Aspects of the washout of salmonid eggs.

4. Effects of a standard mechanical shock, applied at different stages of development, upon survival and development of eggs of brown trout (*Salmo trutta* L.).

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FRESHWATER BIOLOGICAL ASSOCIATION

PROJECT 73

Report to: Department of the Environment,
Ministry of Agriculture, Fisheries & Food,
Natural Environment Research Council,
Northumbrian Water Authority,
Water Research Centre,
Welsh Office.

Date: 19 April, 1985

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D.T. Crisp & S. Robson

CONTENTS

SUMMARY

1. In 1983-4 and 1984-5 experiments were performed on brown trout (Salmo trutta L.) eggs to examine the effect of a standard mechanical shock (c. 2,500 ergs in 1983-4 and c. 8,400 ergs in 1984-5) at various stages of development upon survival to hatching and time of hatching.

2. Survival to hatching in unshocked eggs was c. 95.5% and handling prior to shock treatment had no measurable effect on survival.

3. Shock treatment had no measurable effect on survival if applied before water hardening, during the first 3 to 5 hours of water hardening; and had little effect after the completion of c. 60% of development to median hatch.

4. A shock of c. 2,500 ergs at 22% development to median hatch reduced survival to 84 ± 5.4% but had no detectable effect at later stages of development.

5. A shock of c. 8,400 ergs caused substantial reduction in survival for eggs shocked between 12 and 54% of development to median hatch. The largest observed effect was at 12% development (48% survival). At c. 22% development shocks of c. 2,500 and c. 8,400 ergs gave survivals of 84% and 60% respectively.

6. Brown trout eggs appear to be less sensitive to mechanical shock by impact than coho salmon eggs.

7. The survival of 48% amongst eggs given a shock of c. 8,400 ergs at 12% development to median hatch is similar to the survival of c. 50% observed in previous experiments amongst eggs drifted along 10 m of experimental channel.

8. The administration of mechanical shock, even at shock intensities and stages of development where there is no discernible effect on survival, appears to modify the time taken to reach 50% hatch. The pattern of change, in terms of its direction and magnitude, appears to be rather complex and may be influenced by the intensity of the shock, the manner in which the shock is imparted and the developmental stage at which it is given.

INTRODUCTION

It is generally accepted by fish culturists that salmonid eggs are sensitive to mechanical shock and that the sensitivity varies with the stage of development of the eggs. In general, the period of greatest sensitivity is thought to occur between fertilization and "eyeing". However, it is reasonable to expect that, during a period (perhaps of several hours) following fertilization, sensitivity will be low because in nature during this period the eggs may be subject to some mechanical shock caused by the parent fish covering them with gravel.

The methods used to impart mechanical shock experimentally have been briefly reviewed by Jensen & Alderdice (1983). They include dropping eggs into water from an arbitrary height, simulating water disturbances over redds and the use of vibrators. Jensen & Alderdice devised relatively refined apparatus for dropping eggs from known heights in a standard manner. They found that their technique produced results which closely approximated those obtained by pouring eggs from similar heights into water.

Previous examinations of sensitivity to mechanical shock have concentrated on eggs of Pacific salmon (*Oncorhynchus* spp.) and have given rise to conflicting results. For example, Smirnov (1954, 1955, 1975) and Ievleva (1967) shocked eggs by means of a vibrator and observed a rapid increase in sensitivity within minutes of fertilization, followed by a period of reduced sensitivity and then a further increase which lasted to the eyed stage. In contrast, other workers (e.g. Jensen & Alderdice) subjected eggs to impact rather than vibration and observed a stepwise increase in sensitivity up to completion of epiboly, after which sensitivity decreased.

Recent work in Teesdale has shown that the drifting of brown trout eggs along 10 m of experimental channel can impart sufficient mechanical shock to kill 55-65% of eggs at 13-20% of development to median hatch date but has no detectable effect on the survival of eggs at 60-70% of development to median hatch date (Crisp & Cubby, 1984 unpubl.). Drifting at both these stages of development caused a delay of about one week in attainment of median hatch. During the course of drifting 10 m along the experimental channel at c. 80 cm s^{-1} each egg will, on average, make c. 10 - 20 bed contacts (Crisp, 1984 unpubl.).

The present report describes experiments during 1983-4 and 1984-5 in which eggs at several different stages of development were subject to a standard impact in order to obtain information on variation in sensitivity during the course of development.

MATERIAL

The brown trout (Salmo trutta L.) material used in 1983-4 was obtained by stripping 3 female brown trout of 32.3 to 39.7 cm length and 3 males, all collected from Cow Green reservoir. On 28 October 1983, after fertilization, the eggs were mixed and 1,600 of them were counted into eight batches of c. 200 eggs for experimental use. In 1984-5 six female Cow Green trout of 30.2 to 35.9 cm and six males were stripped and 2,000 eggs were divided into ten batches of c. 200 eggs. An additional experiment using salmon eggs (Salmo salar L.) from N. Tyne material was also started in the autumn of 1984. However, there were very high mortality rates not related to the experimental treatment and no useful results were obtained. The remainder of this report concentrates on the experiments with trout eggs.

A summary of water temperatures during incubation is given in Table 1 and predicted development towards median hatch date (Crisp, 1981) is summarized in Table 2.

METHODS

In each year throughout the period from fertilization to completion of hatching the batches of eggs were held in identical mesh-sided boxes under similar flow conditions. The boxes were examined at frequent intervals (1-3 days) and dead eggs and hatched alevins were removed and counted on each occasion.

The shock treatment consisted of gently pouring the eggs from their rearing box into a plastic container with a mesh bottom which allowed surplus water to drain off. The eggs were then poured out of the container, at a standard height above the water surface, into a bucket containing 15 cm depth of water. The original rearing box was placed at the bottom of the bucket and received most of the eggs. Any eggs which fell outside the rearing box were discarded. Those within the rearing box were retained and reared on. The height from which the eggs were dropped was 30 cm in 1983-4 and 100 cm in 1984-5. Batch 8 in 1983-4 and Batch 10 in 1984-5 were used as controls and have been designated "C_1". Experiment 5 in 1983-4 occurred at the same time as experiment 4 but consisted of preparing

TABLE 1. Mean water temperatures.

1983 - 1984		1984 - 1985	
Month	Mean water temp. (°C)	Month	Mean water temp. (°C)
October (28-31)	6.4	October (26-31)	8.7
November	6.3	November	6.9
December	4.5	December	4.5
January	2.7	January	1.4
February	1.6	February (1-26)	1.2
March (1-20)	2.9		

TABLE 2. Percentage completion of development towards 50% hatching date of brown trout eggs at various times during the periods of observation. In 1983-4, "experiment 8" was the control (C_1) and experiment 5 (C_2) was a repetition of experiment 4, except that the eggs were handled but not shocked. In 1984-5 "experiment 10" was the control (C_1) and experiment 6 (C_2) was a repetition of experiment 5, except that the eggs were handled but not shocked.

1983-4			1984-5		
Event	Date	Predicted % development towards 50% hatch	Event	Date	Predicted % development towards 50% hatch
Eggs fertilized	28 October	0	Eggs fertilized	26 October	0
Experiment 1	28 October	0	Experiment 1	26 October	0
Experiment 2	28 October	0.3	Experiment 2	26 October	0.4
Experiment 3	11 November	21.9	Experiment 3	31 October	12.0
Experiment 4	25 November	38.5	Experiment 4	5 November	21.6
Experiment 5	[25 November	38.5]	Experiment 5	12 November	32.9
Experiment 6	19 December	64.5	[Experiment 6	12 November	32.9]
Experiment 7	9 January	85.5	Experiment 7	16 November	39.2
			Experiment 8	27 November	53.8
(Predicted 50% hatch	31 January - 2 February)		Experiment 9	12 December	76.6
			(Predicted 50% hatch 16-17 January)		

the eggs for shocking and then gently returning them to the rearing box as a test of the effects of pre-shock handling. Similarly for experiments 6 and 5 respectively in 1984-5. These handling experiments have been designated "C_2".

In both years experiments 1 and 2 were performed on the day of fertilization, experiment 1 before water hardening and experiment 2 some 2 to 5 hours later.

The paper of Jensen & Alderdice (1983) was not available at this laboratory until shortly before the 1983-4 experiments began. They concluded that the technique we used gave similar results to those obtained from their more sophisticated apparatus and there is, therefore, some validity in comparing our results with theirs. They suggested that the work imparted to an egg in their apparatus could be estimated, by assuming complete conversion of potential to kinetic energy, as $E = MGH$, where E is the potential energy, M is the mass of an egg (g), G is the acceleration due to gravity (981 cm s^{-2}) and H is the drop height (cm). The application of similar assumptions to our method facilitates comparison of results.

Most authors have described the stage of development of eggs in terms of definable embryonic stages. This involves detailed embryonic examination of the material. In the present work the development has been defined in terms of estimated percentage development to median hatch date. This approach is simpler but less exact. However, it has considerable advantages in field application of the results because it can be predicted from observed incubation temperatures and thus avoids the need to actually handle or, even, see the eggs. Jensen & Alderdice incubated their coho salmon eggs at 10°C and noted that 50% hatch occurred after 45 days. The equations of Crisp (1981) indicate that brown trout eggs would attain 50% hatch in 41 days at 10°C. The assumption that the rate of development of coho salmon eggs at any given temperature is similar to that of brown trout can, therefore, be used as a valuable, though approximate, basis for comparison and has been so used in the present report.

The results have been processed in the manner described by Crisp & Cubby (1984, unpubl.).

RESULTS

The numbers of eggs in each batch, losses during shocking and numbers surviving are shown in Table 3, together with estimates of percentage survival, after exclusion of losses during the shock treatment. Plots of the results are shown in Figure 1.

TABLE 3. Summary life table for the trout eggs used in the experiments.

1983-84

BATCH	1	2	3	4	(5)	6	7	(8)
Starting number	200	200	200	199	200	201	200	201
Loss during shocking	5	4	13	39	-	14	28	-
Survivors to hatching	191	180	157	148	191	176	162	192
% survival(excluding loss during shocking)± 95% C.L.	97.9 ±2.1	91.8 ± 3.9	84.0 ±5.4	93.1 ±4.0	95.5 ±2.9	93.7 ±3.6	94.6 ±3.5	95.5 ±2.9

1984-85

BATCH	1	2	3	4	5	(6)	7	8	9	(10)
Starting number	212	188	197	200	193	199	183	200	200	199
Loss during shocking	1	0	2	4	9	0	2	1	1	0
Survivors to hatching	197	162	94	118	115	190	132	145	178	77
% survival (excluding loss during shocking)± 95% C.L.	93.4 ±3.4	86.2 ±5.0	48.2 ±7.2	60.2 ±7.0	62.5 ±7.1	95.5 ±2.9	72.9 ±6.6	72.9 ±6.3	89.4 ±4.4	38.7 ±6.9

The 1983-4 control batch and the eggs which were handled but not shocked in 1983-4 and 1984-5 gave survivals to hatching of 95.5%. However, the 1984-5 control had a lower survival than any of the experimental batches. There is no obvious explanation for this but it must be attributed to some accidental circumstances not related to the experimental treatments. The results, therefore, indicate that, in both years, unshocked eggs could attain 95.5% survival to hatching and that the handling which was preliminary to the shock treatment did not itself influence the survival rate. The C_2 egg batches can, therefore be regarded as additional controls. The survival of eggs shocked before water-hardening and for a few hours after fertilization (during water hardening) did not differ appreciably from the control value of c. 95%.

Application of a shock of 2,540 ergs (1983-4) depressed survival of eggs shocked at 21.6% development to median hatch to 84% and this is significantly lower than the expected value of 95.5%. A shock of 2,540 ergs at other stages of development did not cause a statistically significant reduction in survival.

A shock of 8,390 ergs (1984-5) caused appreciable reduction of survival in eggs shocked between 10 and 55% of development to median hatch. The lowest recorded survival was 48% in eggs shocked at 12% of development to median hatch.

These results indicate that the shock treatment can cause appreciable mortality of trout eggs but that the magnitude of the effect is related to the amount of shock imparted and the developmental stage of the eggs at the time of shocking. The results agree with the lore of hatchery managers and with the scientific findings for Oncorhynchus in N. America, in showing that the eggs are most vulnerable to the effects of impact

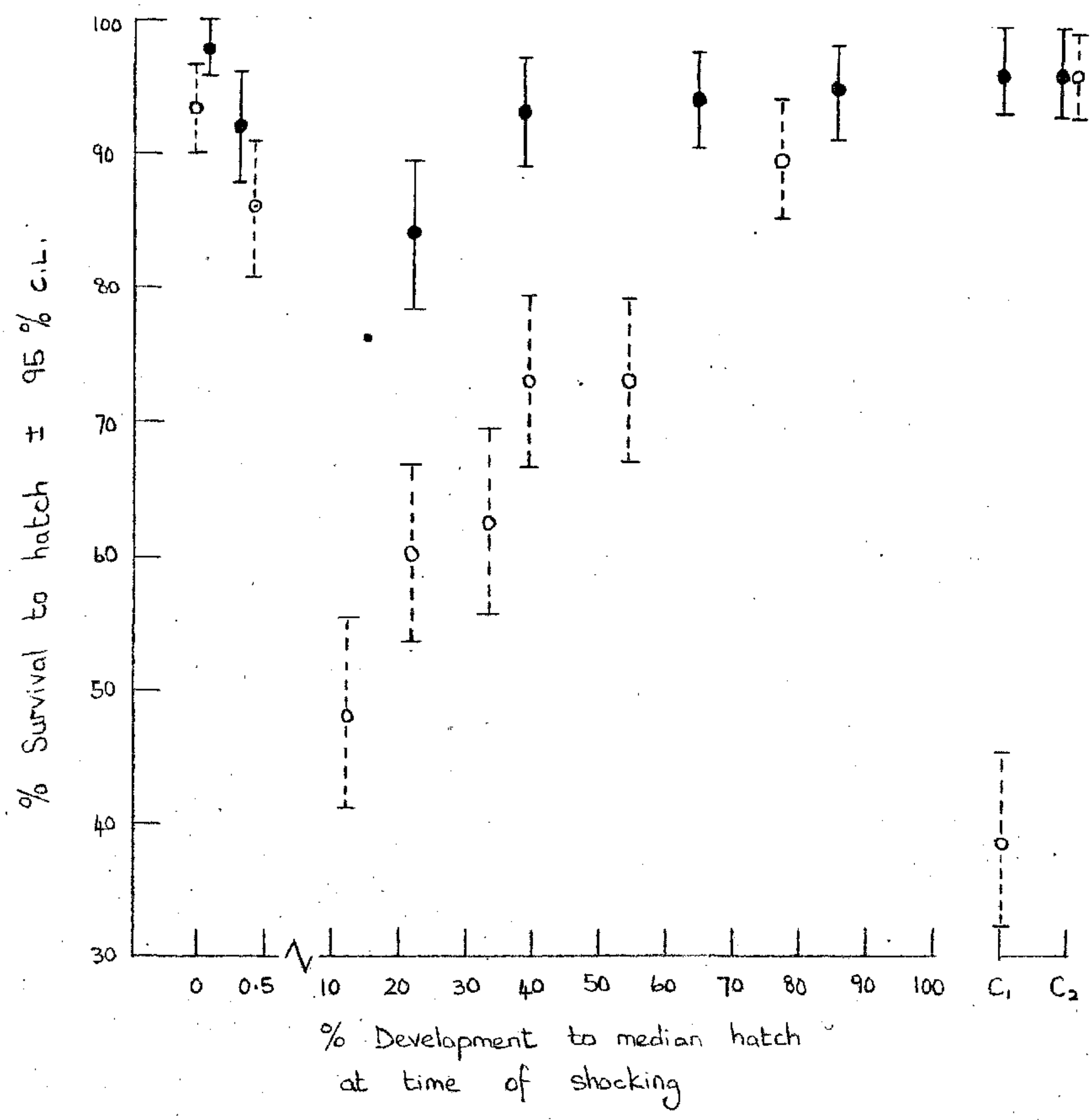

Figure 1. Percentage survival to hatching relative to percentage of completed development to median hatch for trout eggs in 1983-4 (•) and 1984-5 (o). C_1 = Control batch; C_2 = eggs handled but not shocked at 38·5% development to median hatch in 1983-4 and at 32·9% in 1984-5. In 1983-4, the newly fertilized eggs received a shock of c. 2290 ergs and the water hardened eggs a shock of c. 2540 ergs. Corresponding values for 1984-5 were c. 6850 ergs and c. 8390 ergs respectively.

between the completion of water-hardening and the time of eyeing (i.e. c. 50% of development to median hatch).

Median hatch dates for the controls were predicted as 1 February in 1984 and 17 January, 1985. Observed dates were 6 March, 1984 and 28 January, 1985. The difference of ten days between prediction and observation in 1985 was unexceptional. However, the difference of over one month in 1984 was unusual. In past experiments the observed and predicted dates of hatching have usually been within a few days of one another (e.g. Crisp & Cubby, 1984 unpubl.). There is no obvious explanation for the 1984 result, but, as the predictive model is a simple mathematical description of complex biological processes, an occasional faulty prediction might be expected.

The observed dates of median hatch are shown in Figure 2. In both years there was a general tendency for eggs shocked at an early stage of development to hatch earlier than eggs shocked at later stages. In the 1983-4 material hatching of eggs shocked at less than 50% development to median hatch was earlier than for eggs in the control batches and batches shocked at stages later than 50% development hatched at about the same time as the controls. In 1984-5 the material shocked at less than 10% development hatched about 2 weeks earlier than the controls, material shocked at between 10 and 50% development hatched at about the same time as the controls and batches shocked at >50% development hatched 6 to 10 days later than the controls. The relationship between development at the time of shocking and the date of 50% hatch can be represented by a linear regression. Appropriate lines are shown on Figure 2 and summarized in Table 4.

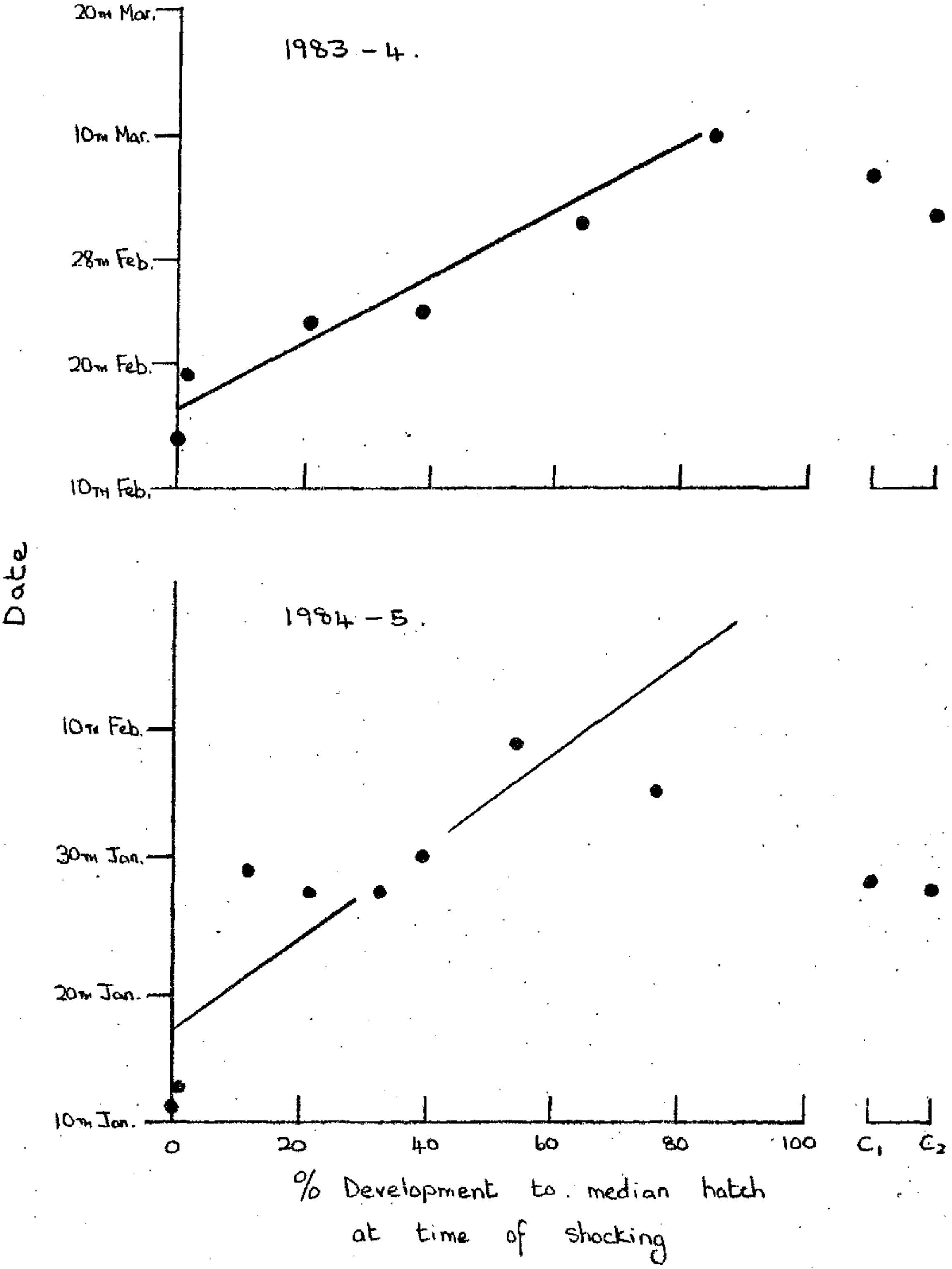

Figure 2. Dates of 50 % hatch for the 1983 - 4 and 1984 - 5 egg batches. Calculated regression lines are also shown.

TABLE 4. Summaries of linear regressions relating day number (x) of date of 50% hatch (y) to percentage development to median hatch at the time of shocking. For the 1983-4 data day number 1 = 10 February and for the 1984-5 data day number 1 = 1 January.

	1983-4 data	1984-5 data
n	6	8
a	6.397	17.362
b	0.240	0.326
r	0.97	0.84
P	<0.001	<0.01

DISCUSSION

1. General comments

A really satisfactory study of the effects of mechanical shock upon the survival of eggs of any given salmonid species would require adequate replication of the experiments and tests of a wide range of shock intensities at a large number of developmental stages. Such an approach requires extensive hatchery facilities and a large input of labour. Neither of these were available in the present study and, therefore, the data leave much to be desired. However, within their limitations, the results do give useful information for one British salmonid species.

2. Effects of mechanical shock upon survival

Although inadequate to give a detailed view of the effects of stage of development at the time of shocking upon survival of trout eggs, the data do show:

a. Maximum sensitivity to impact shock occurs between water-hardening and 50% development to median hatch (50% = about the time of eyeing).

b. Shocking at up to 8,390 ergs immediately after fertilization, and during a period 3 to 5 hours after fertilization, has little effect upon survival.

This general pattern is consistent with the more detailed information for coho salmon in Jensen & Alderdice (1983).

The shock of c. 8,390 ergs in 1984-5 at c. 12% of development to median hatch gave a survival of 48%. This is similar to the survival of 45-55% for eggs drifted 10 m in an experimental channel at 13-20% development to median hatch (Crisp & Cubby, 1984 unpubl.).

The brown trout eggs used in our experiments showed little mortality when subjected to a shock of 2,540 ergs but mortality c. 50% occurred in the most sensitive stages as a result of a shock of 8,390 ergs. In the experiments of Jensen & Alderdice (1983) mortality of 50% was caused by shocks of from 4,395 to less than 2,747 ergs during the first 3 to 16 days development at 10°C (i.e. approximately 10-40% of development to median hatch). This strongly suggests that the eggs of coho salmon are considerably more sensitive to mechanical shock by impact than are the eggs of brown trout. It would be valuable to have some comparable data for the Atlantic salmon.

3. Time taken for development

In experiments on trout eggs drifting in experimental channels, Crisp & Cubby (1984, unpublished) found that allowing eggs to drift a distance of 10 m at 13.5, 19.7, 59.5 and 69.2% of development to median hatch delayed development to 50% hatch by 8 to 11 days. The present experiments also showed modification of the date of 50% hatch as a result of shock treatment, though the modification was generally a reduction in time to hatching and could be related to the stage of development at the time of shocking.

All of the experiments show that sublethal mechanical shock can modify the time taken to attain 50% hatch, relative to the time taken by unshocked eggs. However, the direction and magnitude of the change in timing varied between experiments and probably depended upon a complex of factors which could include the method of shock application, the intensity of the shock and the stage of development of the eggs at the time of shocking. It is also important to note that the hatching of salmonid eggs does not occur at a closely definable stage of embryonic development. Therefore, there are two possible mechanisms whereby shocking could influence the time of hatching:

a. By modifying the rate of embryonic development.

b. By having no effect on the rate of embryonic development, but having some effect on the exact stage at which the embryo emerges from the egg.

The present data shed no light on this particular question.

ACKNOWLEDGMENTS

The authors are indebted to Mr. P.R. Cubby for help in obtaining the eggs and to Mr. B. Martin for help at all stages (particularly in tending the eggs during incubation).

The work was done as part of a contract for the Department of the Environment, Ministry of Agriculture, Fisheries & Food, Natural Environment Research Council, Northumbrian Water Authority, Water Research Centre and the Welsh Office.

The report was typed by Mrs. D. Jones.

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APPENDIX I. PHYSICAL DATA ON EGGS OF BROWN TROUT AND ATLANTIC SALMON.

INTRODUCTION

Crisp (1984, unpublished) included some information on the dimensions, weight and dry matter content of trout eggs at various stages of development. During the studies summarized in the present report additional data on a further set of brown trout eggs and on a single set of salmon eggs was obtained. Details of the provenances of these eggs are given on p. 2 above. This appendix is a combined summary of all these data.

METHODS

The methods were outlined by Crisp (1984, unpublished).

RESULTS

The results are summarized in Table i. The general pattern observed was common to the two sets of trout eggs and to the salmon eggs and its main features were:

1. Throughout the course of development after water-hardening there was no detectable change in the dimensions, weight or water content of the eggs. The values given in the Table for water-hardened eggs are means of values obtained at all stages after the completion of water-hardening.

2. The uptake of water during water-hardening increased the diameter, volume and fresh weight of the eggs by 7 to 12% to give a dry matter content of 31-34% and a density of c. 1.07 g ml^{-1}. The density of the dry matter in the eggs was 1.21 to 1.22 g ml^{-1}.

TABLE i. Summary of physical data on eggs of brown trout and Atlantic salmon.

Material	Diameter (cm)	Volume (ml)	Fresh weight (g)	Dry weight (g)	% dry matter	Density ($g\ ml^{-1}$)	Density of dry matter ($g\ ml^{-1}$)
Trout 1983-4							
Before water-hardening	0.51	0.071	0.0777	0.0291	37.2	-	-
After water-hardening	0.54	0.081	0.0863	0.0277	32.6	1.071	1.221
Trout 1984-5							
Before water-hardening	0.50	0.066	0.0702	0.0271	38.6	-	-
After water-hardening	0.53	0.080	0.0856	0.0272	31.4	1.069	1.217
Salmon 1984-5							
Before water-hardening	0.57	0.097	0.1022	0.0376	37.3	-	-
After water-hardening	0.59	0.105	0.1122	0.0381	33.9	1.071	1.209