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Influence of Electroshock and Mechanical Shock on Survival of Trout Eggs

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Abstract.—Tests were conducted to determine if electric current applied by electrofishing equipment had an effect on trout egg mortality. Eggs of rainbow trout *Oncorhynchus mykiss* were exposed to a standardized mechanical shock and to electric current from a backpack electroshocker. To separate the effect of handling from the electroshock effect, one group of control eggs was handled the same as electroshocked eggs, but without exposure to electricity. Another control group was not handled at all. Samples of eggs were exposed to one of the three treatments on days 2, 4, 6, 8, 10, 12, 14, 16, 18, 22, or 26 postfertilization. The shocker output was measured at 0.6 A, pulse was 250 Hz, and the uniform voltage gradient in the exposure chamber was 0.9–1.0 V/cm. The most sensitive time in the development of the eggs to both mechanical and electrical shock was on day 8 postfertilization when incubated at 10.4°C; treatment at this time resulted in a mortality rate (determined on days 26–27 postfertilization) of 99% for mechanically shocked eggs, 57.9% for electroshocked eggs, and 29.8% among controls handled the same as the eggs that received the electroshock. The mortality of eggs that were not handled at all was 19.7%. Results from further tests with eggs of cutthroat trout *O. clarki* showed that the level of electric current used does have an effect on the survival of trout eggs. We also demonstrated that cutthroat trout eggs placed in artificial redds in a stream can be killed by the same level of current used in these tests. Our findings indicate that electrofishing over recently deposited trout eggs can increase mortality.

Electrofishing, a commonly used sampling technique, is known to injure and sometimes kill fish (Hauck 1949; Schreck et al. 1976; Sharber and Carothers 1988). Spinal injuries are the most common form of permanent injury noted in large salmonids. Although this may cause some mortality, the effect of nonlethal trauma has not been fully evaluated. Progress is being made, but questions remain concerning the sublethal effects of electrofishing (Kolz and Reynolds 1989).

Some reports indicate that electroshock reduces survival of eggs after brood stock or eggs have been shocked, but results are not universal. Marriott (1973) showed that by applying 5 A at 110 V of 60-Hz AC to female brood stock of pink salmon *Oncorhynchus gorbuscha*, egg viability was reduced by 11.8%. He also showed that shocking freshly fertilized eggs held in a metal container increased mortality. Apparently, the effect is minimal in rainbow trout *O. mykiss* if the period between application of the shock and spawning is long enough (Maxfield et al. 1971). Godfrey (1957) exposed several stages of eggs of brook trout *Salvelinus fontinalis* to 1.7 A at 550 V of DC for 30–300 s. Mortality of early cleavage eggs after exposure on day 6 postfertilization was 44.4% for 30-s exposure and 100% for 180-s or longer exposure.

Fertilized salmonid eggs become increasingly sensitive to mechanical disturbance as development progresses. After a particularly sensitive point is reached, sensitivity to handling decreases (Post et al. 1974; Leitritz and Lewis 1976). D. Erdahl (unpublished data) has defined the effect of a standardized physical shock on rainbow trout eggs during development. Our objective was to determine the degree of trout egg sensitivity to electroshock

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and if there is a period of increased sensitivity that coincides with the developmental stage when eggs are most sensitive to mechanical shock. The stage of greatest sensitivity to mechanical shock is early to mid-epiboly, as the blastoderm commences to thin and overgrow the yolk (Hoar and Randall 1988; Post et al. 1974; Erdahl, unpublished data).

Methods

A Living Stream® fiberglass tank, 208 cm long × 55 cm wide × 49 cm deep, was used as an exposure chamber; water was 45 cm deep. The electrodes were pieces of sheet metal, 47 × 56 cm, placed 104 cm apart into the screen holders at both ends of the tank for support. The surface of the electrodes covered the entire cross-sectional area of the tank. A backpack shocker was connected to the electrodes, producing a homogeneous electric field. This was verified with a voltage gradient probe attached to a digital voltmeter.

Eggs were incubated in 9 × 9 × 3 cm screen baskets, which were placed in Heath® incubator trays. The top tray was not used so that the eggs would not be exposed to continuous light. Eggs were only exposed to subdued light for 5–6 min when the baskets were removed for exposure to the test treatment.

In the first set of tests, we used Kamloop strain rainbow trout eggs spawned from 20 pairs at Ennis (Montana) National Fish Hatchery. The eggs were incubated at 10.4°C and were exposed to one of the treatments on day 2, 4, 6, 8, 10, 12, 14, 16, 18, 22 or 26 postfertilization. This period included the incubation period from 2 d postfertilization to 2 d before hatch. Each treatment comprised three replicates of 200 eggs each. In the first treatment, eggs were dewatered then exposed to a standardized mechanical shock: they were dropped 15 cm onto a soft plastic bumper. Each egg was allowed to strike the plastic bumper squarely.

In the second treatment, eggs were gently poured from the wire screen basket in the incubator, into a nylon basket in a Heath incubator tray floating in the center of the 10°C exposure chamber. The eggs were shocked with a Coffelt® BP-6 backpack shocker for 10 s and then gently poured back into the wire screen basket and returned to the incubator. The shocker controls were set at 340 V and 250 Hz. Output was measured at 0.6 A; average voltage was 93 V and peak voltage from an oscilloscope measurement was 365 V of pulsed DC, or 3.8 times the mean voltage. The average voltage gradient as measured with the digital voltmeter in the exposure chamber was 0.9–1.0 V/cm. Conductivity was 270–340 μS/cm at 8°C.

In the third treatment, eggs were handled in the same way as eggs in the second treatment, except that the electric current was not applied. These eggs were intended to help differentiate between the effects of simple egg-handling procedures and electric shock. These eggs were referred to as "handled controls." We also maintained six baskets of 200 eggs each, which were not handled at all. These eggs were referred to as "nonhandled controls."

For all treatment groups in the first set of tests, mortality was determined on days 26–27 postfertilization. Dead eggs were counted and the number was divided by the total number.

A second set of tests was conducted with eggs of Yellowstone cutthroat trout *O. clarki* and the Coffelt Mark 10 shocker with CPS^tm wave form. These tests were conducted to determine the effect of voltage level and duration. Eggs incubated at 10°C were exposed to one of four different electrical treatments on day 8 postfertilization. Triplicate groups of 200 eggs were exposed to 250, 400, 550, or 700 V for durations 5, 10, or 20 s. The eggs were the progeny of 25 pairs of McBride Lake, Yellowstone cutthroat trout that are reared at the Yellowstone Fish Hatchery near Big Timber, Montana. Handling procedures were as described above. Eggs were counted 10 d after being shocked, at about the eye-up stage of development, to determine percent mortality.

We also tested to determine if electric current could be measured in the interstices of the gravel in the streambed. Artificial redds were constructed in Bridger Creek. The voltage gradient probe was inserted 20 cm into the gravel, and the leads were attached to a voltmeter. Electric current was generated with the BP-6 shocker set at 340 V output at 250 or 500 Hz.

Artificial redds were also used to determine the effect of electroshock on cutthroat trout eggs under simulated natural conditions. Redds were constructed in a 1.83 × 18.3 m concrete raceway. Exactly 200 fertilized eggs were placed into each Vibert box, and two boxes were placed in each of nine redds. The boxes were set on a gravel base and covered by 20 L of washed 0.64–1.27-cm gravel to a depth of about 15 cm. Water flowed over the redds at about 91 cm/s. Three redds were randomly selected for each of two treatments. On day 8 postfertilization, the redds were shocked for 10 s with pulsed DC from the BP-6 shocker set at 340 V or the Mark 10 set at 550 V with the CPS waveform. The current gradient was 0.9–1.0 V/cm

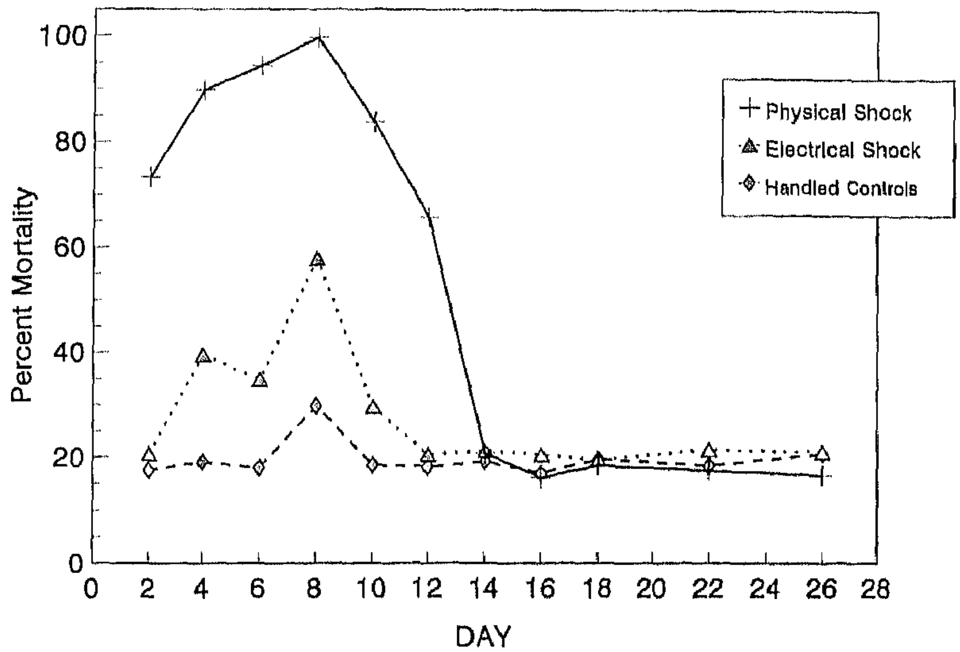

FIGURE 1.—Percent mortality (mean) of rainbow trout eggs exposed to physical shock or electrical shock, and of control eggs handled in the same way except without exposure to shock. Different eggs were treated at different stages of development (day = days postfertilization), and mortalities of all treatment groups were determined on days 26–27 postfertilization.

for each treatment, as measured with the voltage gradient meter. Three redds were not shocked and served as controls. At 10 d after treatment, the Vibert boxes were removed and eggs were counted to determine percent mortality.

Data was analyzed with an unweighted means analysis of variance, and significant differences among the means were identified with the Newman–Keuls range test at the 0.05 level of significance (Hintze 1987). Significance between the two treatments and the control were determined for each day, and the analysis was also made to identify days when mortality was highest within each treatment. Data from the egg redd exposure were analyzed with the Mann–Whitney test (Snedecor and Cochran 1967). Differences were considered significant at $P = 0.05$.

Results

Electroshocking affected survival of rainbow trout eggs. The first set of experiments showed that the most sensitive time in the development of the eggs was on day 8 postfertilization at 10.4°C. Treatment on day 8 resulted in a mean mortality (SD) of 99% (0.1%) for eggs exposed to physical shock, 57.9% (4.9%) for those exposed to electrical shock, and 29.8% (3.5%) for handled controls (Figure 1; Table 1). Mean percent mortality in unhandled controls was 19.7% (1.13%).

Statistical analysis showed that the 99% mean mortality of physically shocked eggs treated on day 8 postfertilization was not significantly higher than the 94.4% mortality of those treated on day 6 postfertilization. The mean of 89.8% resulting from treatment on day 4 was significantly lower than the day-8 mean, but not significantly lower than the day-6 mean. All of the mean mortalities for the physically shocked groups treated on days 2–12 were significantly greater than the mortalities

TABLE 1.—Percent mortality of rainbow trout eggs exposed to electrical shock or physical shock, and of control eggs handled in the same way except without exposure to shock. Mortalities of all treatment groups were determined on days 26–27 postfertilization.

Treatment day[a]	Handled controls		Electrical shock		Physical shock	
	Mean	SD	Mean	SD	Mean	SD
2[b]	17.5	3.08	20.6	1.76	73.3	5.74
4[c]	19.1	3.75	39.5	3.62	89.8	4.29
6[c]	18.0	0.36	34.8	3.47	94.4	6.06
8[c]	29.8	3.51	57.9	4.87	99.0	0.10
10[c]	18.5	2.67	29.6	1.48	83.7	1.25
12[b]	18.2	2.86	20.5	0.76	65.7	3.72
14[d]	19.2	3.52	21.3	3.47	20.8	0.29
16[d]	17.0	0.76	20.5	4.01	16.1	4.98
18[d]	19.7	2.05	19.6	2.62	18.5	3.82
22[d]	18.5	2.48	21.5	4.39	17.5	1.65
26[d]	20.7	5.02	21.0	0.72	16.6	0.81

[a] Days postfertilization.
[b] Significant difference between the physical shock treatment and the other two treatment means ($P \le 0.05$).
[c] Significant difference between all means ($P \le 0.05$).
[d] No significant differences among the treatment means ($P > 0.05$).

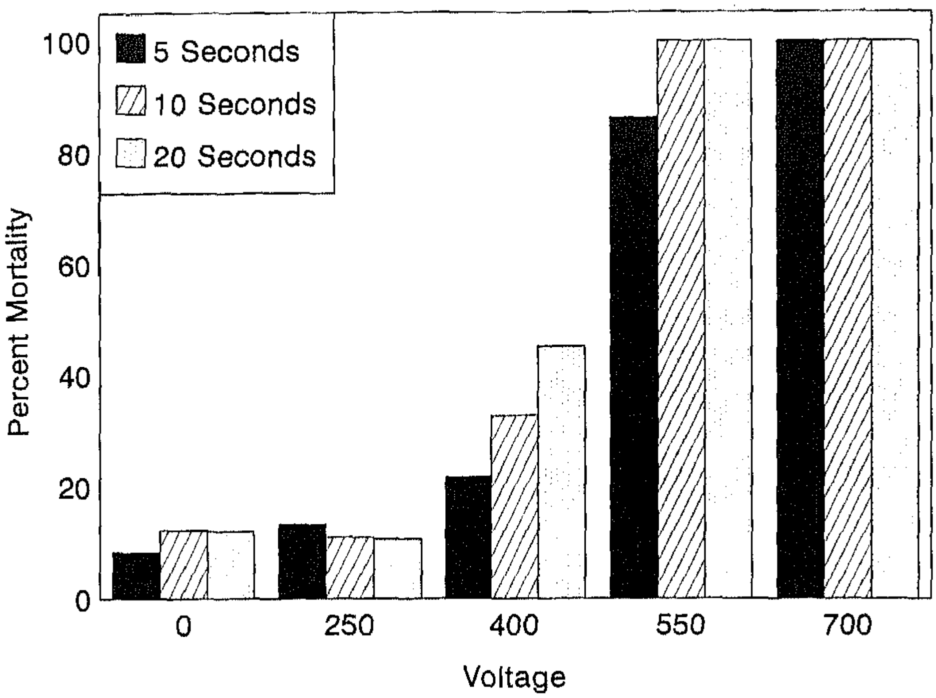

FIGURE 2.—Percent mortality (mean) of cutthroat trout eggs exposed to electroshock in tanks at one of four voltages and three time durations on day 8 postfertilization. The control group was not exposed to electroshock (0 V). Mortality was determined 10 d after treatment.

of those treated on days 14–26. There is a much greater resistance to handling later in development and the eggs were quite sensitive to handling and physical shock on treatment days 4, 6, and 8 postfertilization (Table 1).

The mortality of the eggs electroshocked on day 8 was significantly greater than the mortalities of groups electroshocked on any of the other treatment days. There was no difference in mortality between treatment days 6 and 4, and days 6 and 10, but there was between treatment days 4 and 10. All mortality was greater than that for treatment on days 2 and 12–26, among which there was no difference (Table 1).

The mortality of the eggs that were handled but did not receive any electroshock was also the highest for those treated on day 8 postfertilization. Mortality was 29.8% for eggs treated on day 8, and 17.0 to 20.7% for eggs treated on days before or after day 8. This again indicates that the eggs were most sensitive to handling at day 8 postfertilization.

The percent mortality in the physically shocked eggs was significantly greater than that of the electroshocked and control eggs for treatment days 2–12 (Table 1). The mortality of electroshocked eggs was greater than that of the controls for days 4–10, and there was no difference between mortality after any of the treatments on days 14–26.

The tests with Yellowstone cutthroat trout eggs treated on day 8 postfertilization showed that intensity (voltage) and duration of the shock are positively correlated with mortality (Figure 2). Mortality rate of eggs exposed at 400 V best demonstrated that as exposure duration increased from 5 to 20 s, mortality rate also increased. Comparison between treatment and control groups showed that at 250 V there was no effect of duration on mortality; at 700 V there was no effect due to duration because mortality was always nearly 100%.

There was a significant difference between the percent mortality of the eggs exposed to electric current for 5, 10, and 20 s at the 400-V setting. At the 550-V setting, mortality of the 5-s exposure group was lower than mortalities of the 10- and 20-s exposure groups. There was no significant difference in mortality among the control eggs and egg groups exposed to the 250-V settings. There was also no difference in mortality among groups exposed to electrical current at the 550-V settings for 10 and 20 s, or among groups treated at the 700-V setting for any of the exposure durations.

Voltage gradient levels as high as those to which the eggs were exposed in the test chamber were easily achieved in the artificial redds (1.0 V/cm). Voltage gradient appeared to be negatively affected by gravel depth when the 250-Hz setting was used; however, when the unit was set at 500 Hz, nearly every reading was 1.0 V/cm or higher.

TABLE 2.—Percent mortality of cutthroat trout eggs (N = 200/sample) placed in artificial redds on day 8 postfertilization and shocked (10 s) with a BP-6 electroshocker set at 340 V or a Mark 10 electroshocker set at 550 V. Mortality was determined 10 d after treatment.

Sample	Control	BP-6	Mark 10
1	63.0	89.5	97.5
2	53.5	61.0	99.0
3	57.5	55.0	92.5
4	51.0	70.0	92.5
5	47.5	63.5	97.0
6	62.5	69.5	94.0
Mean[a]	55.8	68.1	95.4
SD	6.27	11.89	2.78

[a] All means were significantly different from each other ($P \leq 0.05$).

Results of the tests with cutthroat trout eggs in Vibert boxes in the artificial stream channel showed significant egg mortality from electroshock (Table 2). Mortality in controls was high (56%) because of sedimentation; however, it was higher in redds exposed to electrical current. Egg mortality was 68% in redds shocked with the BP-6 set at 340 V, and 95% in redds shocked with the Mark 10 at 550 V. Mortality differences between both treatments and between the treatments and the control were statistically significant ($P \leq 0.05$).

Discussion

It has long been known that trout eggs are sensitive to physical shock or handling during development (Rutter 1902; Wales 1941). The data from this study indicates that trout eggs are also sensitive to electroshock. Susceptibility to electroshock mortality was related to stage of egg development, intensity of shock, and duration of exposure. Our findings indicate that electrofishing over recently deposited trout eggs can increase mortality. Caution should be exercised when electrofishing around redds, especially where populations of wild fish are dependent on natural reproduction.

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