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=RESEARCH NOTES=

Effects of Electrofishing on Fish Embryos, Larvae, and Early Juveniles Part II.

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Electric fields are of no value in the collection of fish eggs and few researchers have applied electrofishing technology to the collection of fish larvae and early juveniles (Snyder 1983; Copp 1989). Accordingly, most of the concern over adverse effects on fish eggs and larvae is with regard to incidental exposure during electrofishing operations for larger fish. However, as noted by Lamarque (1990), information on the effects of electric fields on early-life stages of fish is sparse and limited primarily to salmonids.

Kolz and Reynolds (1990) surmised that the sensitivity of embryos to electrofishing is similar to that of mechanical shock and Lamarque (1990) cautioned that, because of the sensitivity of embryos between fertilization and eyed stages, electrofishing over active spawning areas should be avoided. For brook trout (*Salvelinus fontinalis*) and Atlantic salmon (*Salmo salar*) embryos, Godfrey (1957) found sensitivity to electric fields was low through the first few hours (water hardening; precleavage stages), then high until the embryos were eyed, and low again thereafter. Dwyer and Fredenberg (1991) and Dwyer et al. (unpubl. ms. 1992) compared the effects of mechanical and electrical shock on rainbow trout (*Oncorhynchus mykiss*) embryos and documented differences in sensitivity from 2 to 26 days after fertilization for embryos cultured at 10C (at this temperature, most eggs eyed-up at day 18 and hatched at day 28). They found that sensitivity followed a nearly normal distribution for both types of shock with peaks at day 8. Mortalities during this most sensitive time (day 8) averaged 99% for embryos subjected to mechanical shock (eggs dropped 15 cm from one container to another), 58% for those exposed for 10 seconds to a homogeneous electric field of pulsed direct current (250 hertz or pulses per second, mean voltage gradient of 0.9-1.0volts/cm, peak voltage gradient of about 3.4-3.8volts/cm), 30% for handled but unshocked embryos, and about 20% for unhandled controls. (Homogeneous electric fields are usually restricted to containers or troughs of uniform width and depth and are characterized by constant voltage gradients between fully cross-sectional electrodes. In contrast, normal electrofishing fields are heterogenous with voltage gradients rapidly decreasing with distance from the electrodes.)

Newman and Stone (unpubl. ms. 1992) tested the viability of 24-hour and 48-hour walleye (*Stizostedion vitreum*) eggs that were exposed to an electrofishing field. The eggs were placed in nylon mesh bags which were laid on a lake bottom over typical walleye spawning substrate. They were exposed to a single pass of the electrofishing boat (pulsed direct current-120 hertz, 400 volts, 3 amps, quarter-sine waveform). Mortality for 24-hour eggs exposed to the electrofishing field was 64% whereas unshocked controls experienced 45% mortality. In tests with the 48-hour embryos, mortality was 56% for exposed eggs and 53% for controls; although small, the difference between exposed and unexposed eggs was statistically significant. Noting that the incubation period for walleye eggs is much shorter than for trout eggs and that peak sensitivity to mechanical shock occurs at about 24 hours of age, the authors suggested that for walleye embryos, the 24th hour also approximates the peak period of sensitivity to electric fields (comparable to the 8th day for rainbow trout).

Embryos may also be detrimentally irritated by electric fields near the end of the embryonic period. Luczynski and Kolman (1987) used alternating current to induce precocious hatching in powan (*Coregonus lavaretus*) embryos.

Godfrey (1957) found that for brook trout and Atlantic salmon exposed to direct current (unpulsed), mortality increased with exposure time and field intensity. Dwyer and Fredenberg (1991), Dwyer and Erdahl (1992) and Dwyer et al. (unpubl. ms. 1992) arrived at the same conclusion based on their own experiments with 8-day cutthroat trout (*Oncorhynchus clarki*) embryos exposed to pulsed direct current. Mortalities observed after exposure to 5, 10, or 20 second of Coffelt's *CPS* waveform (a pulse train of three 240-hertz pulses every fifteenth of second) in a homogeneous field were approximately 100% at a peak voltage gradient of about 6.7 volts/cm, 85-100% at about 5.3 volts/cm, 20-45% at about 3.8 volts/cm, and less than 15% for both 2.4 volts/cm and for unshocked controls.

Scheminzky (1922 according to Lamarque 1990) subjected (brown?) trout (*Salmo trutta*?) eggs to long exposures in a direct-current field and reported movements of embryos and one incident of high mortality. Exposures in Scheminzky's experiments were far longer than those likely in normal electrofishing operations (Lamarque 1990), but perhaps they were not so different from conditions near some electric screens or barriers which might affect floating or pelagic eggs such as freshwater drum (*Aplodinotus grunniens*), emerald shiner (*Notropis atherinoides*), or striped bass (*Morone saxitilus*).

Based on a limited experiment with precleavage Atlantic salmon eggs buried under about 20 cm of gravel and exposed to direct current for about 2 minutes, Godfrey (1957) concluded that eggs in gravel redds received some protection from shock (mortality 10% versus 81% for unburied eggs). In a similar experiment, Dwyer and Erdahl (1992) and Dwyer et al. (unpubl. ms. 1992) subjected 8-day (cutthroat?) trout eggs buried in artificial redds to backpack-electrofishing fields. Cumulative mortalities 10 days after exposure were 96% for the Coffelt *CPS* waveform at 550 or 700 peak volts, 68% for 250-hertz or 500-hertz pulsed direct current at 340 or 380 (peak?) volts, and 56% for unshocked controls. The high mortality for the controls and a portion of each shocked group was attributed to sedimentation in redds. As a result of this and other experiments noted above, Dwyer et al. (unpubl. ms. 1992) concluded that electrofishing in streams where trout have recently spawned can adversely affect egg survival.

Among the few researchers who have used electric fields to capture larvae, Maty et al. (1986) used them to capture Atlantic salmon larvae upon emergence from redds and Noble (1970) used an electric grid in front of a Miller high-speed sampler to successfully improve the catch of larger larvae and juveniles. Noble (1970) found the field had little effect on the catch rate of smaller larvae. However, because smaller fish larvae are much less likely to evade the sampler, catch rates for the smaller larvae might not be expected to differ even if the field was effective.

Perhaps the greatest proponent for electrofishing as a sampling method for larvae and small juveniles is G. H. Copp of France. Copp and associates (Copp 1989, 1990; Copp and Penaz 1988; Persat and Copp 1990) utilized the same portable pulsed-direct-current electrofishing gear that is used locally for larger fish but reduced the size of the anode to a 10-cm ring and increased the size of the cathode to sufficiently intensify the field around the anode to induce taxis or narcosis (tetany?) in fish as small 5 mm standard length. This resulted in an effective field diameter of 30 cm or less for most larvae and small juveniles. For larger fish, it is generally recommended that both electrodes be as large as possible to reduce the zone of tetany and maximize the effective size of the field. However, Copp and his associates effectively used their very limited range to advantage by combining the method with a sampling strategy that consisted of numerous, small, randomly distributed, microhabitat samples (Point Abundance Sampling). With this approach, the anode, on a 2.5 m handle, was dipped into the water as the deadman switch on the handle was closed, the net and current were maintained there for a second or two, and then a fine mesh dip net was thrust under the anode to collect the fish. The advantage over simply using dip nets or hand seines was a relatively unbiased size range. The matter of electrofishing injuries and mortality with this sampling method and design would not have been a serious concern because sample size was usually very small and larval and small fish samples were fixed and preserved for subsequent processing. But this might not be the case in other early-life-stage sampling or monitoring programs.

The effects of electrofishing on early-life stages appear to vary with species and size. Godfrey (1957) observed that in response to a direct current, newly hatched Atlantic salmon (*Salmo salar*) exhibited increased swimming movement but not the anodic taxis expected among older fish. Maxfield et al. (1971) noted that 30-second exposures to homogeneous, low-frequency, pulsed-direct-current fields with a peak voltage gradient of 1 volt/cm failed to induce narcosis in 5-cm young-of-the-year rainbow trout whereas exposures to similar fields at a voltage gradient of only 0.75 volts/cm were sufficient to induce narcosis in at least some 19-cm yearlings. Among adverse effects, Lamarque (1990) noted that mortality was common for larval pikeperch (*Stizostedion lucioperca*) but rare for trout larvae; also that salmon parr did not suffer unduly in fields that killed larger smolt. Lamarque (1990) suggested that electric fields that are dangerous to adults would likely also be dangerous to juveniles, but because fish larvae and early juveniles are extremely fragile, mortality due to handling and the stress of capture would likely be as great as that due to electrofishing fields. The occurrence and significance of physical electrofishing injuries to fish larvae and early juveniles was not documented in literature reviewed for this report and probably remains to be investigated.

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