with my Compliments Peter Sorensen

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Effects of Electroshocking on the Sexual Behavior of Goldfish and Brook Trout

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Abstract.—I investigated the effect of electroshocking on the reproductive behavior of goldfish *Carassius auratus* and brook trout *Salvelinus fontinalis*. In the laboratory, 24 h after being stunned by 400-V pulsed DC, male and female goldfish spawned normally with sexually active conspecifics. Similarly, in an uncontrolled field study, nearly half of male and female brook trout collected by DC electroshocking on their spawning redds and subsequently released were later seen spawning. Although these results suggest that electroshocking does not have long-lasting effects on the behavior of two species of sexually mature fish, caution is still advised when using electroshocking to sample wild spawning fish.

While studying the physiological basis of salmonid spawning behavior, I realized that the only way to collect fish on their spawning nests (redds) was to use a stationary electroshocking technique. In reviewing the literature on electroshocking to determine if this technique was suitable for use on spawning fish, I found that, although the effects of electroshocking on the behavior and physiology of nonreproductive fish are relatively well studied (Schreck et al. 1976; Mesa and Schreck 1989; Schneider 1992), not a single study had investigated the effects of electroshocking on fish reproductive behavior and physiology. Indeed, the only reports related to this topic were on the fertility of gametes taken from fish subjected to electroshocking. Two of these reports suggest that electroshocking does not induce lifelong sterility in juvenile largemouth bass *Micropterus salmoides* and rainbow trout *Oncorhynchus mykiss* (Elder 1954; Maxfield et al. 1971), but a third describes a decrease in the fertility of eggs (but not sperm) taken from chinook salmon *Oncorhynchus tshawytscha* killed by electrocution (Marriott 1973). I found this poor understanding of the effects of electroshocking on fish reproduction quite disconcerting, given the obvious importance of reproductive behavior to species survival, the ease with which spawning behavior can be disrupted, and the well-established fact that electrofishing causes spinal damage (Sharber and Carothers 1988) and short-duration hormonal and behavioral changes in nonreproductive trout (Mesa and Schreck 1989). Accordingly, I undertook the present study to determine whether electroshocking affects the propensity of sexually mature fish to spawn. The study had two components: a controlled laboratory study that used goldfish *Carassius auratus* and a correlational study of the reproductive activity of wild brook trout *Salvelinus fontinalis* that were shocked on spawning redds in a small temperate stream.

A controlled study of the effects of electroshocking on goldfish reproductive behavior was possible because the endocrinological basis of this species' reproductive behavior is well established and can be manipulated (Sorensen 1992). Briefly, female sexual receptivity in goldfish is stimulated by circulating prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$), which is produced in response to the presence of eggs in the reproductive tract (Stacey 1976). Circulating $PGF_{2\alpha}$ is also rapidly metabolized and excreted by female goldfish where it then functions as a sex pheromone that triggers male sexual behavior (Sorensen et al. 1988). Receptivity and pheromone release can be stimulated in goldfish simply by injecting them with as little as 0.1 μg of synthetic $PGF_{2\alpha}$. Within 15 min of injection goldfish will exhibit spawning behavior if provided with spawning substrate (e.g., floating weeds) and sexually mature male(s), even though they have no eggs to release (Stacey 1981). If, however, a female goldfish injected with $PGF_{2\alpha}$ is subjected to stressful conditions or if no male is present, it will not spawn (Sorensen, unpublished). Circulating $PGF_{2\alpha}$ thus stimulates sexual receptivity (the proclivity to spawn), not the actual behavior; $PGF_{2\alpha}$ is thought to have similar actions in many other species of fish (Stacey and Goetz 1982; Sorensen and Goetz 1993).

Sexually mature goldfish ranging in total length from 12 to 15 cm were purchased from Ozark Fisheries (Stoutland, Missouri) in the spring of

1990 and maintained in 1,000 L flow-through tanks on a light : dark cycle of 18:6 h at 18°C for up to 3 months until needed. Male and female goldfish were then selected on the basis of their propensity to spawn with each other, after the females had been injected intramuscularly with 10 μg of $PGF_{2\alpha}$, dissolved in physiological saline (Cayman Chemicals, Ann Arbor, Michigan). Selected fish were marked with distinctive fin clips on their dorsal and pectoral fins and placed into 70-L glass aquaria (60 × 30 × 40-cm). Twelve males from these aquaria were subsequently moved into other 70-L glass aquaria, containing flowing 18°C water (0.25 L/min; conductivity, 350 μS/cm) as well as floating yarn balls and gravel. Thirty-two responsive females were then randomly divided into two groups and their spawning behavior quantified 15 min after being injected with 10 μg of $PGF_{2\alpha}$; they were placed with males between 0900 and 1200 hours. As the pretest, the behavior of these pairs of fish was observed from behind an observation blind for 30 min and the frequency of completed spawning acts noted with an event recorder. In goldfish, a spawning act is typically initiated by the female, which ceases swimming away from the male and assumes a head-up position in the weeds. The act of spawning occurs when the female and accompanying male, who is generally at her side, roll over in the weeds together and the female flips her tail, a behavior normally associated with egg release. Sperm release by the male is often apparent at this time. To ensure a balanced experimental design, females were always spawned with the same males and the same males were used with both groups of females.

After the pretest, the females were either lightly anesthetized (as a control) in an aquarium containing 1:10,000 concentration of MS-222 (tricaine methanesulfonate; Syndel Laboratories, Vancouver) for 5 min or placed into an aquarium where they were exposed to 15-s pulsed DC (400 V, 1-A peak intensity, 100 rectangular pulses/s, 25% duty cycle) administered by Quadrapulse APB-450-1Q backpack electroshocker (University of Wisconsin Engineering Technical Services Center, Madison). Electrodes were metal machine bolts, 10 cm long and placed 25 cm apart at the ends of the aquarium. Free-swimming fish were exposed to this current when they swam into the middle of the aquarium and their body axis was parallel to the axis of the aquarium. Stunned fish floated to the bottom in a rigid C-shaped configuration but did not touch the electrodes. Stunned fish took at least 10 min to regain their equilibrium and start swimming, at which time they were returned to their aquaria. No darkening of their pigmentation, which is indicative of internal injury, was observed. Twenty-four hours after being stunned, fish were again injected with $PGF_{2\alpha}$ and transferred to a tank containing the male with which they were originally tested, and their spawning behavior was quantified. The effect of electroshocking on male behavior was then tested in the same way as female behavior with the exception that males were now shocked or anesthetized and their tendency to spawn with females injected with $PGF_{2\alpha}$ was monitored. Twenty-four males (12 per group) were tested. Mean spawning frequencies were then plotted and compared by means of a repeated measures analysis of variance (SYSTAT Inc., Evanston, Illinois). No treatment effects were apparent (Figure 1; $P > 0.05$).

Having failed to find any indication that electroshocking influenced goldfish spawning behavior, I conducted a field test in Valley Creek, Minnesota (water conductivity, 500 μS/cm; for map and description see Elwood and Waters 1969) with brook trout captured by a stationary electroshocking technique. Briefly, this technique employed two 1-m-long copper pipes as electrodes, which were placed approximately 2 m upstream and downstream of the spawning site and connected via cables to a remotely activated electroshocking generator (T & J Manufacturing, Oshkosh, Wisconsin), which produced a rippled DC (250 V, 3 A; Novotny and Priegel 1971). I chose to sample an area located at the outlet of a small pool that I knew (from observations conducted in 1989) was used by spawning brook trout for at least several weeks, was readily accessible and easily monitored, and was the only spawning site for at least 25 m. The sampled area was about 30 cm deep and 3 m wide. Average water temperature was 10°C. An observation blind was set up at this location and fish observed spawning were collected by electroshocking (using 30-s pulses) once a day. Captured fish were immediately anesthetized in a solution of 1:5,000 2-phenoxyethanol (Eastman Kodak Chemicals, Rochester, New York), had a sample of blood drawn with a syringe (for another study), and had their adipose fin clipped (for subsequent identification). They were revived in a bucket of stream water and then released at the capture site. In all, 11 male and 9 female, reproductively active, brook trout were caught during a 2-week period, and all were released in good condition. Of the released fish, 5 males and 3 females were observed again at the same location

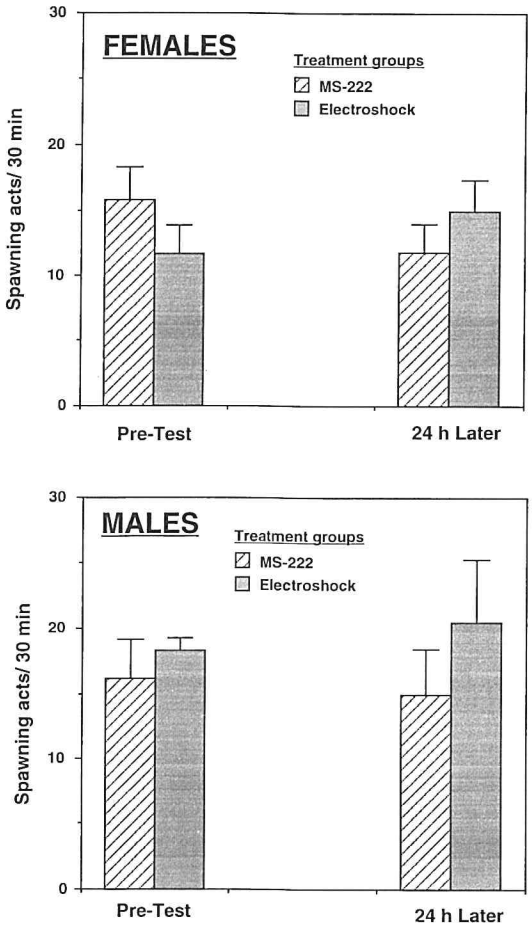

FIGURE 1.—Mean frequency of spawning acts during a 30-min period for individual male and $PGF_{2\alpha}$-injected female goldfish before and after exposure to either an electric shock or anesthetic (MS-222, tricaine methanesulfonate). No differences were present between any group with respect to either time or treatment ($P > 0.05$). Bars represent standard error of the mean.

either spawning or attempting to spawn. One large male with distinctive natural markings, and which appeared to have a dominant status, was shocked and released three times. The shortest time between capture and resumption of spawning activity was 1 d, with 2 d being most common. Although the spawning behavior of these previously shocked fish appeared normal, I do not know what happened to the fish which were not seen spawning again or whether the shocking had influenced the reproductive success of any of the fish.

In conclusion, the present study did not produce any compelling evidence to suggest that DC electroshocking has long-lasting effects on the sexual behavior of either male or female goldfish or brook trout. However, it is extremely important to realize that the study was limited in several ways. First, I only investigated the behavior of fish that were already in a physiological (endocrinological) condition conducive for spawning; the possibility that electroshocking might evoke longer-lasting changes in endocrinological state, which might eventually lead to behavioral deficits, was not addressed. Second, my study was restricted to two species that are relatively tolerant of handling stresses. Third, we did not investigate the possibility that other electroshocking protocols (e.g., AC current) might have more dramatic effects on fish behavior. In conclusion, although I have no reason to suggest that electroshocking per se has adverse effects on fish reproductive activities, I recommend that it be used judiciously when sampling sexually active fish because of the limited scope of the present study, the fact that electric currents are known to induce mortality in pre-eyed salmonid eggs (Godfrey 1957), and because exposure to all stressful events should be minimized during this critical stage in a fish's life.

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