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Effects of Direct Current Electrofishing on the Mottled Sculpin

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Abstract.—We examined the effects of electrofishing on the survival of mottled sculpin *Cottus bairdi* in two experiments. Three tanks each were filled with mottled sculpin collected by electrofishing (treatment) and by kick-seining (control). We maintained these tanks for at least 30 d and recorded all deaths. Patterns of survival were not significantly different among tanks in either of the experiments. In addition, there were no significant differences between pooled data sets (all control tanks versus all treatment tanks) within each experiment. Failure to demonstrate a treatment effect in either experiment suggests that electrofishing does not adversely affect the short-term survival of mottled sculpin. Although sample sizes were insufficient for statistical analysis, a similar result was obtained for several other species of stream fishes. To test the effects of multiple electrofishing exposures, we conducted another experiment in four artificial stream sections. Treatment mottled sculpin were shocked, and both treatment and control fish were handled, weekly, for 5 weeks. Although overall survival in all stream sections was lower than that seen in the first two experiments, there were no significant differences in survival among sections or between treatments in this experiment. These data suggest that handling stress was a greater determinant of mortality rates than was electrofishing.

Electrofishing, a commonly used sampling technique, may cause mortality or physical injury to fishes (Hauck 1949; Horak and Klein 1967; Lamarque 1967; Spencer 1967; Schreck et al. 1976; Whaley et al. 1978). For example, electrofishing has caused broken and dislocated vertebrae and ruptured blood vessels in rainbow trout *Salmo gairdneri* (Hauck 1949; Horak and Klein 1967), brook trout *Salvelinus fontinalis* (Hudy 1985), bluegill *Lepomis macrochirus*, largemouth bass *Micropterus salmoides*, and channel catfish *Ictalurus punctatus* (Spencer 1967). In addition, a variety of sublethal effects (e.g., changes in blood physiology) have been noted in fishes after electroshocking (Schreck et al. 1976; Bouck et al. 1978; Burns and Lantz 1978; Gatz et al. 1986).

For many types of studies, it is important to assess the effects of electrofishing on fish populations. Researchers making repeated censuses (e.g., mark–recapture studies or long-term population dynamics studies) must avoid techniques that result in fish mortality to reduce the risk of biasing their results (Pratt 1954). In addition, electrofishing effects should be known before this technique is used on endangered or threatened fish populations.

Most prior studies on the effects of electrofishing have not dealt with nongame species. In addition, the effects of multiple exposures to electricity have not been well documented. We examined the acute effects of both single and multiple exposures of nonpulsed direct current on the mottled sculpin *Cottus bairdi*.

Methods

Single-exposure experiments.—We collected two groups of mottled sculpin from Dryman Fork, at the Coweeta Hydrologic Laboratory, Otto, North Carolina, in late February and early March 1985. Dryman Fork is a fourth-order stream of low conductivity (annual range, 10–15 μS) and low average temperature (annual range, 2–19°C; mean, 8°C). Temperature at the time of collection was 5–8°C. Treatment fish were electroshocked with a Smith-Root, model XI-A, direct current electrofisher set to deliver 600 V of nonpulsed current (200 W continuous output). We used a minnow seine 1–2 m below the electrofisher to collect electroshocked fish. Although this technique may have resulted in the capture of fish with unequal electrical exposures (e.g., heavily stunned fish versus mildly affected fish, etc.), it accurately represents the method of collection used in many studies (Reynolds 1983).

We drove control fishes into the seine by kicking the substrate (i.e., kick-seining). Kick-seined fish were examined visually to insure that they had not been injured during capture. We weighed (±0.5 g) and measured (standard length [SL], ±1 mm) all fishes before randomly placing them into one of six 650-L fiberglass tanks. Three tanks contained control fish, and three tanks contained treatment fish. Each tank was provided with a continuous supply of stream water (approximately 12 L/min), which maintained water temperatures between 5 and 10°C. In each tank we placed 30 mottled sculpin and 20 additional individuals in some combination of seven other species: Tennessee shiner *Notropis leuciodus,* warpaint shiner *N. coccogenis,* longnose dace *Rhinichthys cataractae,* largescale stoneroller *Campostoma oligolepis,* rosyside dace *Clinostomus funduloides,* northern hog sucker *Hypentelium nigricans,* and creek chub *Semotilus atromaculatus.* Low capture success prevented stocking identical numbers of these species in each tank; however, overall species combinations generally were equal in numbers of fish between treatments. Because of the low abundances of these seven species, we will not discuss their results in detail. The mottled sculpin collected ranged from 32 to 87 mm SL (mean ± SD, 55.7 ± 9.7 mm) and from 1 to 15 g in weight (4.14 ± 2.85 g). These six tanks will be referred to as experiment I.

In late June and early July 1985, we collected two more groups of mottled sculpin from Dryman Fork using electrofishing (treatment fish) and kick-seining (control fish) for use in experiment II. Water temperature at the time of collection, and in the tanks during the course of this experiment, varied between 14 and 16°C. These fish were marked with subcutaneous injections of acrylic paint and introduced into the same six tanks used for experiment I. Subcutaneous marking has been shown to have no statistically detectable effect on the survival of mottled sculpin (Hill and Grossman 1987). At this time, one of the experimental and two of the control tanks still contained several experiment-I fish, which were being kept for long-term analysis. Consequently, to keep the total density of fish in each tank constant, we had to introduce unequal numbers of mottled sculpin into each tank for experiment II. The total number of fish introduced varied from 11 to 33 individuals (mean, 19). These sculpin ranged from 36 to 89 mm SL (mean ± SD, 56.5 ± 10.4 mm) and from 1 to 16 g in weight (4.27 ± 2.69 g). Experiment-I and experiment-II fish could be differentiated by the presence of acrylic marks.

We fed experiment-I fish a diet of brine shrimp, chopped earthworms, and a commercial flake food 5–6 times a week. This diet was changed to a homogenate of beef liver, brine shrimp, and commercial flake food, mixed with cod liver oil, gelatin, agar and vitamins C, E, and A for experiment II. In addition, during experiment II, we also added malachite green (0.1 mg/L) and formalin (25 mg/L) to the tanks for 1–2 h once or twice weekly as a prophylaxis.

For both experiments, we cleaned and inspected the tanks one or two times per week, removed any dead fishes, and recorded their length and condition. If death occurred between tank inspections, the date of mortality was taken to be the midpoint between the date the specimen was found and the previous inspection date. Although some fish from each experiment lived 90 d or more, problems with disease outbreaks after 30+ d in captivity made the detection of electrofishing effects problematical. Consequently, we considered only the first 30 d of each experiment for this analysis.

For each experiment, we tested whether the survival times of fish in the six tanks were significantly different using a Kruskal–Wallis test (P = 0.05 in this and subsequent tests). If the Kruskal–Wallis test was significant, multiple comparisons between tanks were made. Treatment effects, if any, could be inferred from the pattern of significant between-tank differences. We also tested for treatment effects by pooling the data for each treatment (i.e., all control tanks vesus all experimental tanks) and testing for significant differences using a Mann–Whitney test. This latter test was conducted to reduce the effects of intertank variability within a treatment.

Henson Creek experiment.—To test the short-term effects of multiple exposures of electricity on mottled sculpin, we conducted a third experiment. We divided a concrete diversion channel on Henson Creek (Coweeta Hydrologic Laboratory) into four sections (2.4 × 0.6 m each) and then diverted the stream through these sections. Cobbles from the creek were added to create a natural substrate. Natural colonization of the substrate by macroinvertebrates occurred during a 4-week period prior to the experiment. These invertebrates were the only food available to the fish except for a supplemental feeding of mealworms provided in the third week of the experiment. On September 9, 1985, we again collected treatment mottled sculpin by electrofishing and control fish by kick-seining. Water temperatures at the time of collection and during all subsequent collections ranged from

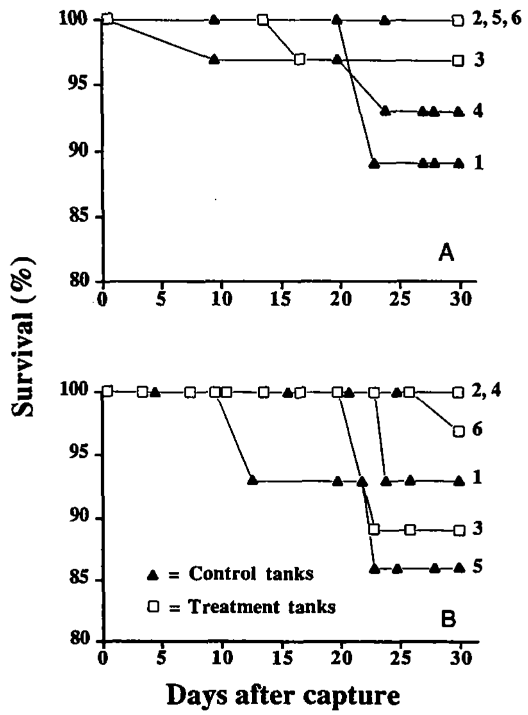

FIGURE 1.—Survival of mottled sculpin after capture by electrofishing (treatment) or kick-seining (control) in experiment I (A) and II (B). Numbers adjacent to lines represent tank numbers.

12 to 14°C. Both groups of fish were weighed and measured, marked with subcutaneous injections of acrylic paint, and randomly released into one of the four sections (two treatment sections and two control sections). These fish ranged from 38 to 79 mm SL (mean ± SD, 55.4 ± 8.5 mm) and from 1 to 12 g in weight (3.88 ± 1.92 g). All the stream sections initially contained 25 mottled sculpin. Each week, for a total of 4 weeks, we electrofished the two treatment sections for 30 s with nonpulsed DC at 600 V (200 W continuous output). All fish were then collected with hand nets and checked for their acrylic paint marks. At weeks 0, 3, and 4, we also weighed and measured these fish. Control fish were treated identically except that the electrodes of the electroshocker were not energized as they passed through the control stream sections. We removed dead fish and calculated survival times as in experiments I and II.

To test the hypothesis that electrofishing had no effect on survival, a Kruskal–Wallis test was used to check for significant differences in the survival time of fish in each section. As in the tank experiments, we also tested for treatment effects by pooling the data for each treatment (i.e., both control sections versus both treatment sections) and testing for a significant difference using a Mann–Whitney test.

Results

Tank Experiments

In experiment I, overall survival of mottled sculpin in each of the tanks exceeded 88% in all cases (Figure 1A). Mottled sculpin survival in the treatment tanks (mean, 99%) exceeded survival in the control tanks (mean, 94%). There were no significant differences in survival times of fish among tanks (Kruskal–Wallis test; $P > 0.10$). Similarly, we also failed to detect a significant difference between pooled survival times of fish in treatment and control tanks (Mann–Whitney test; $P > 0.10$). Thus, mottled sculpin survival in experiment I was not significantly affected by either tank or treatment effects.

In experiment II, overall survival of mottled sculpin in each of the tanks exceeded 85% in all cases (Figure 1B). Survival in the treatment tanks (mean, 95%) slightly exceeded survival in the control tanks (mean, 93%). We could not detect significant differences in the survival times of fish in each tank (Kruskal–Wallis test; $P > 0.10$). We then tested pooled data for treatment and control tanks and found no significant differences (Mann–Whitney test; $P > 0.10$), suggesting that neither tank nor treatment effects were present in this experiment.

Survival times for other species were recorded, but sample sizes were too low to permit statistical testing of these results. Mortality patterns for these species, however, were similar to the patterns observed for mottled sculpin, with little or no mortality during the first 30 d after capture.

Henson Creek Experiment

All fish survived the first 7 d of the experiment. After handling or handling plus electroshocking on days 7, 14, and 21, survival declined in all sections (Figure 2). There were no significant differences in survival of fish from the four stream sections (Kruskal–Wallis test; $P > 0.05$). We also failed to detect a significant difference between the pooled treatment data (sections 2 and 3) and the pooled control data (sections 1 and 4; Mann–Whitney test; $P > 0.10$). Hence, we were unable to demonstrate either a section or treatment effect in this experiment, suggesting that repeated handling rather than electroshocking was responsible for the observed mortality.

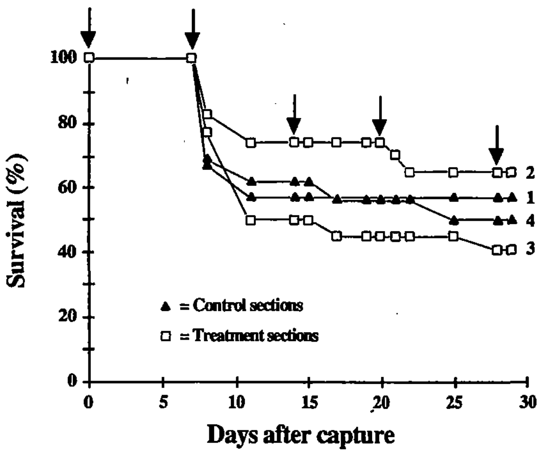

FIGURE 2.—Survival of mottled sculpin subjected to repeated electroshocking and handling (treatment) or just handling (control) in four artificial stream sections at Henson Creek. Black arrows indicate the time of handling and electroshocking episodes. Numbers adjacent to lines represent section numbers.

Discussion

Our experiments indicate that electrofishing did not have a significant effect on mottled sculpin survival (over a 30-d period), regardless of whether the fish experienced either single or multiple exposures to electricity. No mottled sculpin died within 7 d of capture in any of the treatments, and mortalities among fish subjected to a single electrofishing exposure did not begin until 17 d after capture. These results suggest that fish were not acutely injured during collection as has been reported previously for electroshocked fish (Hauck 1949; Spencer 1967; Hudy 1985). The overall mortality among our once-exposed mottled sculpin (0–10.5%) was less than that observed in other investigations (Hauck 1949; Horak and Klein 1967; Spencer 1967) and may be due to our use of direct current electricity, which is less harmful than alternating current (Pratt 1954; Spencer 1967).

If electrofishing does have a deleterious effect on mottled sculpin, that effect should have been most obvious in our Henson Creek experiment where treatment fish were repeatedly exposed to electricity over a relatively short time period. Our failure to detect significant differences in the survival of electroshocked and control fish at Henson Creek strongly suggests that exposure to electricity alone does not result in appreciable mortality in mottled sculpin. Overall survival at Henson Creek, however, where fish were handled repeatedly, was much lower than that observed in our tank experiments, where fish were handled only once. Because a significant electrofishing effect was not detectable in the Henson Creek data, this suggests that handling stress has a greater effect on mottled sculpin survival than does electrofishing. We cannot explain why most mortality at Henson Creek occurred after the second handling and electroshocking exposure (on day 7).

The Henson Creek experiment had several advantages over the tank experiments, including repeated exposure to electricity over a short time period, reduced disease problems, the presence of natural prey, and a more natural habitat. Consequently, we suggest that future studies on stream fishes be done in experimental stream channels rather than in tanks or simulated streams.

There is evidence that exposure to electrofishing produces sublethal physiological changes in fishes, specifically increases in blood lactate and creatine phosphokinase levels (Schreck et al. 1976; Bouck et al. 1978; Burns and Lantz 1978). If such changes occurred in our electroshocked fish, they apparently did not differentially affect survival. Because even mild handling can produce physiological imbalances in fishes (Wedemeyer 1972; Pickering et al. 1982), it may be that control fish in our experiments suffered as much physiological distress as treatment fish. Nonetheless, the lack of a significant treatment effect indicates that any physiological changes produced by electrofishing did not significantly affect mottled sculpin survival.

One difficulty in comparing our results to those from earlier studies is the general lack of methodological uniformity among studies, represented by differences in voltage, type of voltage (i.e., AC, DC, or pulsed DC), water temperature, and water conductivity. Given these differences, it is not surprising that investigators have reported different results for the effects of electrofishing, even for the same species. For example, Kynard and Lonsdale (1975), working with yearling rainbow trout, reported 2% mortality among shocked fish. Hauck (1949) reported a 26% mortality of rainbow trout. Lamarque (1967) found up to 93% mortality for trout (species unknown) that he exposed to electricity. The last study demonstrates the enormous variability in results; Lamarque (1967) found mortality rates ranging from 0 to 93% depending on the fish-to-electrode distance and the type of electrical current used. These examples typify the difficulty in making generalizations regarding the effects of electricity on fish survival.

Our study differed from most others in that it dealt with nongame fishes. All species examined showed similar responses to electrofishing, although we were only able to statistically evaluate data for mottled sculpin. It seems possible, however, that species-specific or situation-specific responses to electrofishing could exist. Consequently, researchers concerned about electrofishing-induced mortality should test the response of their experimental animals before using this technique. Our results indicate that electrofishing in low-conductivity Appalachian streams probably will not cause significant short-term mortality among mottled sculpin. Minimization of handling stress is more likely to eliminate collection-related mortality than would a switch to alternative, nonelectrical modes of collection.

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