Effects of electrofishing on long-term growth and mortality of wild rainbow trout

by Steven Ray Dalbey

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University

Abstract:
Spinal injury rates as high as 67% have been reported in large (>300 mm long) rainbow trout (Oncorhynchus mykiss) collected with pulsed direct current. This study was designed to evaluate how incidence and severity of electrofishing-induced spinal injury in wild rainbow trout affects long term growth and mortality. Three test groups of 241, 309, and 316 fish were collected from the Gallatin River using three waveforms: smooth (SM), 60-Hz half pulse (HP), and 60-Hz full pulse direct current (FP). Spinal injury rates were highest in fish collected with FP (54 %), followed by HP (40 %) and SM (12 %), while class 3 spinal injury (fracture of one or more vertebrae) levels were similar in all three test groups (6% SM, 6% HP, 10% FP). Fish from the three test groups were placed into a 0.61 hectare pond for approximately 1 year where they were subsampled after 100 days and all remaining fish removed after 1 year. Growth and mortality were compared by test group and by severity of electrofishing-induced spinal injury. There was no significant difference in short-term (100 days) or long-term (1 year) growth between the three test groups. However, spinally injured fish exhibited lower growth, less weight gain, and lower condition factor increase than uninjured fish. Test group and severity of spinal injury did not appear to influence overall survival at the termination of the study (54 % SM, 58 % HP and 60 % FP). Although specimens collected with FP and HP exhibited higher total spinal injury rates than those collected with SM, the long-term impacts of this injury were not manifested in decreased growth and survival.

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Steven Ray Dalbey

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Spinal injury rates as high as 67% have been reported in large (>300 mm long) rainbow trout (*Oncorhynchus mykiss*) collected with pulsed direct current. This study was designed to evaluate how incidence and severity of electrofishing-induced spinal injury in wild rainbow trout affects long term growth and mortality. Three test groups of 241, 309, and 316 fish were collected from the Gallatin River using three waveforms: smooth (SM), 60-Hz half pulse (HP), and 60-Hz full pulse direct current (FP). Spinal injury rates were highest in fish collected with FP (54 %), followed by HP (40 %) and SM (12 %), while class 3 spinal injury (fracture of one or more vertebrae) levels were similar in all three test groups (6% SM, 6% HP, 10% FP). Fish from the three test groups were placed into a 0.61 hectare pond for approximately 1 year where they were subsampled after 100 days and all remaining fish removed after 1 year. Growth and mortality were compared by test group and by severity of electrofishing-induced spinal injury. There was no significant difference in short-term (100 days) or long-term (1 year) growth between the three test groups. However, spinally injured fish exhibited lower growth, less weight gain, and lower condition factor increase than uninjured fish. Test group and severity of spinal injury did not appear to influence overall survival at the termination of the study (54 % SM, 58 % HP and 60 % FP). Although specimens collected with FP and HP exhibited higher total spinal injury rates than those collected with SM, the long-term impacts of this injury were not manifested in decreased growth and survival.

INTRODUCTION

Electrofishing has been proven to be directly responsible for spinal and soft tissue injuries in fish. Injuries are thought to occur when fish intercept the electric field which elicits powerful contractions of the body musculature. These contractions are believed to occur simultaneously on both sides of the body, thus generating opposing forces which can compress, misalign or fracture vertebrae (Cowx and Lamarque 1990). Sharber and Carothers (1988) determined that spinal injury was found in 44% to 67% of large (>300 mm long) rainbow trout (*Oncorhynchus mykiss*) electrofished with pulsed direct current (PDC). That study provided the impetus for further investigations dealing with the magnitude and impacts of electrofishing-induced injury on growth and mortality in several freshwater fishes. The Alaska Department of Fish and Game (ADFG) conducted a study on the Kenai River which provided estimates of short-term mortality and injury for large rainbow trout exposed to electrofishing with PDC (Holmes et al. 1990). Forty-one percent spinal injury rate and 14% short-term (96 hours) mortality was observed, thus prompting ADFG to place a moratorium on electrofishing in all waters in Alaska containing trophy rainbow trout (Reynolds undated). A study by the Montana Department of Fish, Wildlife and Parks (MDFWP) on the Missouri River in 1988 to assess electrofishing-induced injury revealed 50 - 70 % spinal injury rates in large rainbow trout (Fredenberg 1992). In his follow-up study involving trout collected from across the state, Fredenberg (1992) found that among 693 electrofished trout, there were 769 hemorrhages and 2,647 injured vertebrae. Present information suggests that electrofishing injury of rainbow trout depends on waveform and pulse shape, rate, duration, and intensity (Gatz et al. 1986).

High injury rates of fish collected with several different PDC waveforms led the MDFWP to issue electrofishing guidelines recommending the use of pulse frequencies of 20 pulses per second or less, short pulse duration (5 msec.), and the lowest possible voltages to minimize injury (Fredenberg 1992). Several studies have observed increased injury rates as a function of the pulse shape and frequency (Spencer 1967; Sharber and Carothers 1988; Cowx and Lamarque 1990; Taube 1992). Fredenberg (1992) observed that increasing pulse frequencies increased incidence of spinal injury and hemorrhage. The lowest injury rate was with smooth DC, followed by half pulse DC (intermediate injury), and full pulse DC (highest overall rates). The use of direct current (as opposed to AC or PDC) is recommended to reduce incidence of injury by Reynolds (undated). In his review of electrofishing, Snyder (1993) also states that when direct current is used, it should be as smooth as possible to minimize the risk of spinal injury.

The long-term effects of electrofishing injury on the growth and survival of wild rainbow trout populations remain largely unknown (Reynolds undated). While several studies have assessed the effects of electrofishing on growth and survival of hatchery rainbow trout and other species (Spencer 1967; Hudy 1985; Gatz et al. 1986; Gatz and Adams 1987; Roach 1992; Taube 1992), investigations to date have not examined the fate of injured wild fish over the long-term (1 year or greater). Furthermore, the potential healing of electrofishing-induced spinal injuries has yet to be investigated.

Based on the need for better information on the long-term effects of electrofishing-induced injury on fishes, this study was designed to:

(1) determine the short-term and long-term growth and survival of wild rainbow trout electroshocked with three different DC waveforms;

(2) compare the relative growth and survival rates of spinally injured and non-injured electroshocked fish; and

(3) evaluate healing of electrofishing-induced spinal injuries.

STUDY AREA

The growth and survival portion of this study was conducted in an irrigation storage pond located on the campus of Montana State University (MSU). This manmade pond is 0.61 hectare with a maximum depth of 4.5 m, a mean depth of 3.5 m, a storage capacity of approximately 19,000,000 L and a regular bottom composed of mud and gravel. The pond is fed by diverted Hyalite Creek water. No surface outflow exists as water is pumped for campus irrigation. The inlet was screened to prohibit any fish movement out of the pond. Water levels fluctuated slightly during summer irrigation months but remained constant throughout the rest of the year. The pond perimeter is secured with a 3 m barbed wire and chain link fence to discourage access.

Prior to introduction of test fish into the pond, existing fish were removed with gill nets. Sixteen brook trout (average length 40.1 cm, average weight of 1.1 kg) were captured the first night, but none the following two nights. These fish were likely transients from Hyalite Creek that were diverted with irrigation water and became trapped in the pond when the ditches were shut down. Freshwater shrimp (*Gammarus lacustris*) were abundant in the littoral areas of the pond. Plankton tows were run on August 10, 1992 yielding abundant Daphnia sp. and Diaptomus sp.. Dissolved oxygen and water temperature measurements recorded during winter months ranged from 8-11.5 ppm and 1.2-5 ^{0}C with no apparent stratification. Summer temperatures ranged from 10 to 26 ^{0}C with the peak temperature recorded on August 1, 1992.

METHODS

Fish Collection

I tested the hypothesis that there is no difference in growth and survival of fish collected with three different DC waveforms by collecting 1,036 wild rainbow trout (153 - 388 mm fork length) via single pass, mobile electrofishing (Fredenberg 1992). Conventional wattage settings on the shocker box were selected as these typically produce high fish collecting efficiency for rivers in the region (Wayne Black, MDFWP, pers. comm.) (Table 1). Fish were collected from a 14 km reach of the Gallatin River, Montana on July 27 and 28, 1992. The sequence of waveforms was smooth (SM), half pulse (HP) and full pulse (FP) (Figure 1). Shocking with each waveform used continued downstream until the target number of fish for each group (330) was captured. This reach of the Gallatin was selected due to a high density of rainbow trout and it had not been electrofished for several years, thus eliminating the possibility of collecting fish that may have electrofishing-induced injury from previous electrofishing operations.

The type of equipment, electrode array design, electrofishing setting, water temperatures, and conductivities associated with test fish collection are summarized in Table 1. Peak voltages were measured at seven measured intervals (Figure 2) from the anode using a set of metal contacts 1 cm apart mounted on a probe and connected to an oscilloscope. These measurements were recorded in order to differentiate power gradients (v/cm) of the three waveforms at specified distances from the anode where the majority of fish netting within the electrical fields occurs. Documentation of electrical and physical variables in this study was conducted to further standardize the reporting of these variables in electrofishing experiments as recommended by Reynolds (undated).

Following collection, fish were transported by hatchery truck to raceways at the U.S. Fish and Wildlife Service Fish Technology Center in Bozeman, Montana. Transport water was tempered for approximately 30 minutes prior to fish being released into outdoor raceways where test groups were held separately.

Table 1. Physical parameters and equipment specifications associated with the collection of wild rainbow trout from the Gallatin River on July 27 - 28, 1992.

Water Temperature (^{0}C)	13 -16
Conductivity (umhos/cm)	260
Water Clarity	Approximately 1 m visibility
Boat	3.6 m Fiberglass Drift
Generator	3,000 Watt Gillette
Anode Configuration	25.4 cm Aluminum Triangle (2.54 cm)
Cathode Configuration	1.2 m^2 Stainless Steel Plate
Shocker Box Type	Leach Box, 220 Volt
Shocker Setting	1,000-1,500 Watt Output

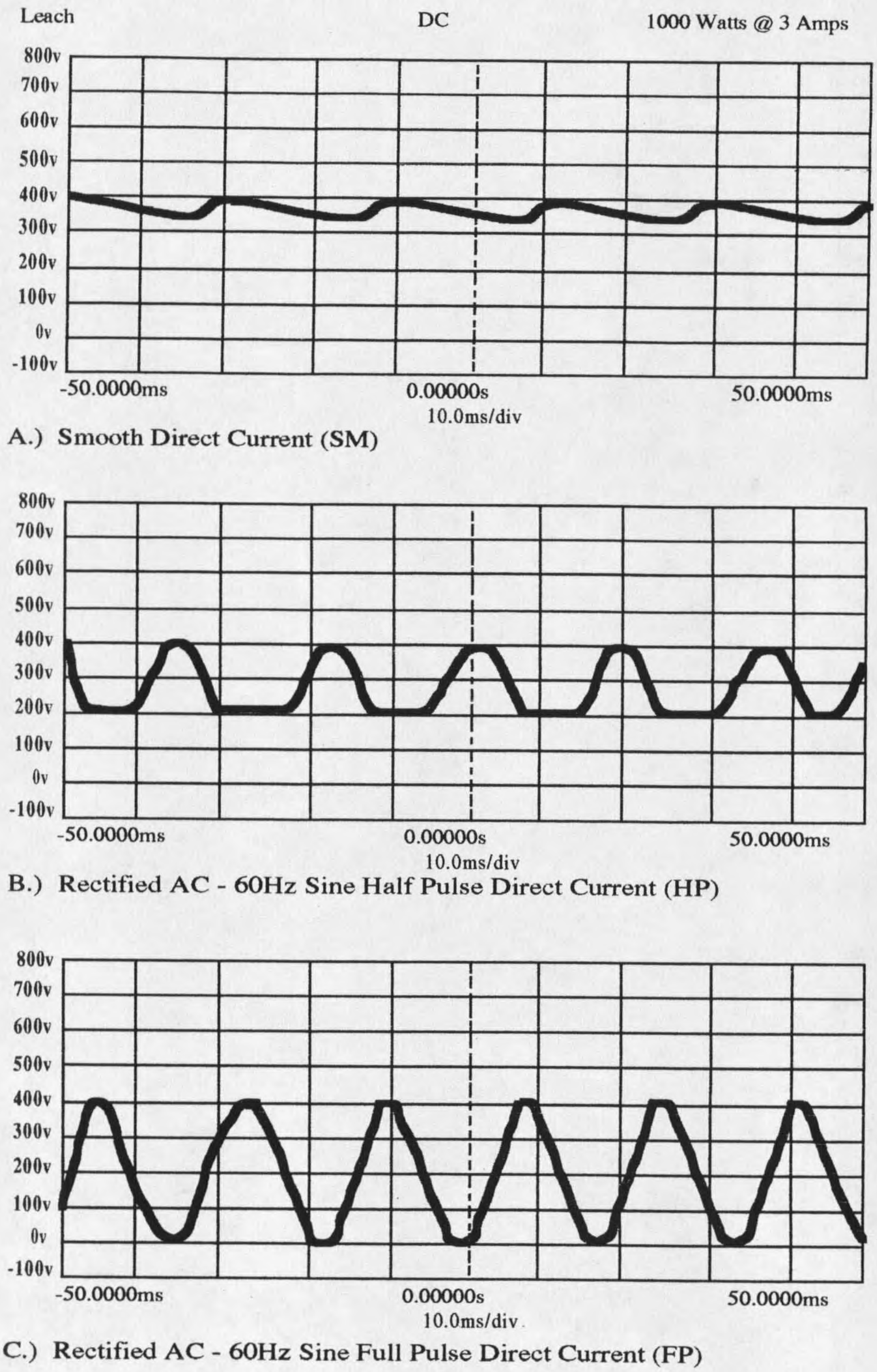

Figure 1. Electrical waveforms used to collect the three test groups of wild rainbow trout from the Gallatin River, Montana on July 27 and 28, 1992. Waveform diagrams generated using a digitizing oscilliscope at 1000 watts and 3 amps (Fredenberg 1992).

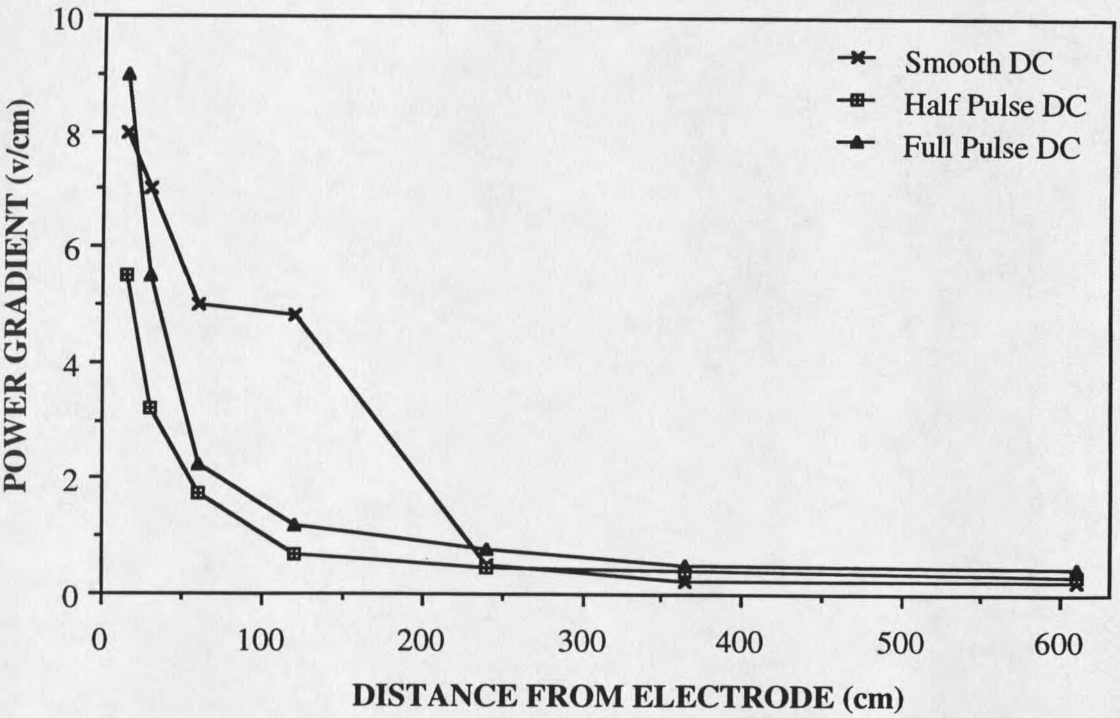

Figure 2. Peak voltage gradients for the three waveforms used to collect wild rainbow trout from Gallatin River on July 27 and 28, 1992.

Weighing, Tagging and X-raying

After 24 h, trout within each test group were moved to indoor raceways for x-raying and tagging. Fish were anesthetized with MS-222 (3.5-4.5 ml of 5% tricaine methanesulfonate per gallon of water) in groups of ten, tagged with a coded wire tag in one of three unique locations to identify test groups, and marked with a visible implant (VI) tag in the postorbital adipose tissue of each fish to identify individuals (Figure 3). Weights and fork lengths were measured and each fish was then placed in a second tub containing 5.0 ml MS-222 per gallon of water where they were held until the entire group of ten fish had been processed. VI tags were verified and fish were x-rayed (right lateral view) with a portable X-ray machine (Minxray X750G) using standard veterinary x-ray film (PC Konica