Injury, Survival, and Growth of Rainbow Trout Captured by Electrofishing

A

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By

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Abstract

Electrofishing injury studies in Arizona and Alaska revealed spinal injury rates of over 50% among large (>300 mm long) rainbow trout *Oncorhynchus mykiss* captured by electrofishing with pulsed direct current (PDC). My goal was to identify an alternative waveform that would efficiently capture large rainbow trout with injury rates less than 15%. Experiments in homogeneous and heterogeneous electrical fields tested six waveforms; lower injury rates resulted with DC (17%), CPS™ (8%), and 20-Hz PDC at 75% duty cycle (25%). In field experiments with these three waveforms, PDC and DC gave higher capture rates than CPS™. However, injury rate was 60% with 20-Hz PDC and highly variable (0-47%) with DC. Long-term mortality of rainbow trout shocked with 60-Hz PDC at 50% duty cycle was 35% after 203 days. I recommend DC as an alternative to PDC waveforms for relatively safe and efficient capture of large rainbow trout.

Introduction

Electrofishing is a method commonly used for the capture of rainbow trout *Oncorhynchus mykiss* in population studies. However, reports of spinal injury, internal hemorrhage, mortality, and effects on growth and physiology of electroshocked rainbow trout appear in the literature. As early as 1949, Hauck (1949) reported 26% mortality rate among large rainbow trout captured with alternating current. Injury rates up to 8% and mortality rates from 2 to 11% have been reported in yearling rainbow trout up to 200 mm long (Pratt 1954; McCrimmon and Bidgood 1965; Horak and Klein 1967; Maxfield et al. 1971; Hudy 1985). Short-term mortality rates up to 14% have been reported for large rainbow trout captured with pulsed direct current (Holmes et al. 1990). Growth of rainbow trout exposed once to electrical waveforms was normal (Maxfield et al. 1971; Kynard and Lonsdale 1975), but instantaneous growth rate in rainbow trout electroshocked more than once within a 12 month period was significantly reduced (Gatz et al. 1986). Studies have also reported behavioral and physiological changes in trout captured by electrofishing (Schreck et al. 1976; Bouck and Ball 1966; Woodward and Strange 1987; Mesa and Schreck 1989).

Sharber and Carothers (1988) reported spinal injury rates between 44-67% in large rainbow trout (mean length=360 mm) captured with three forms of pulsed direct current. These injury results caused concern and precipitated a similar study by the Alaska Department of Fish and Game (ADFG) in 1988 on the Kenai River (Holmes et al. 1990). They found 41% spinal injury and 14% short-term (96 hours) mortality in rainbow trout captured with pulsed direct current. A self-imposed moratorium on electrofishing for rainbow trout in Alaska was established by the ADFG. These events led to the development and funding of this project in cooperation with the ADFG; its purpose was to identify electrical waveforms that caused low injury without significant loss in catch efficiency.

This study focused on internal injury (spinal damage and internal hemorrhage), long-term mortality, and growth of large (>300mm) rainbow trout exposed to various waveforms used in electrofishing. The objectives of this study were to estimate internal injury rates caused by various waveforms; to evaluate the effects of electroshock on long-term survival and growth of shocked and injured rainbow trout; and to confirm the results of the first objective in a field test of the low-injury waveforms. These objectives were achieved through three experiments: (1) a controlled study of injury and mortality; (2) a controlled study of long-term mortality and growth; and (3) a field test of injury, short-term mortality, and catch rates.

Table 1. Voltage gradient, fish length, and rates of injury (95% confidence limits in parentheses) for waveforms used in the homogeneous experiment conducted June 26-29, July 19, 1990 and July 30, 1991 at the Fort Richardson Hatchery, Anchorage, Alaska.

Waveform	n	Voltage gradient (V/cm)		Fish length (mm)		Spinal injury (%)	Internal hemorrhage (%)
		mean	SD	mean	SD		
Low Voltage							
DC	18	0.51	0.16	455	31	33 (13-59)	28 (10-54)
CPS	12	0.12	0.01	412	20	17 (3-49)	33 (10-65)
AC	12	0.21	0.03	464	50	58 (28-85)	25 (6-57)
PDC 60/50	12	0.36	0.10	478	55	58 (28-85)	50 (22-79)
PDC 30/75	12	0.96	0.35	401	27	42 (16-72)	58 (28-85)
PDC 30/50	12	0.70	0.52	410	49	58 (28-85)	42 (16-72)
High Voltage							
DC	18	0.94	0.21	469	33	22 (7-48)	28 (10-54)
CPS	12	0.42	0.08	386	29	25 (6-57)	50 (22-79)
AC	12	3.43	0.51	482	62	75 (43-94)	58 (28-85)
PDC 60/50	12	2.39	0.51	463	55	42 (16-72)	33 (10-65)
PDC 30/75	12	3.45	0.38	399	25	42 (16-72)	33 (10-65)
PDC 30/50	12	2.41	0.35	387	125	33 (10-65)	50 (22-79)
CONTROL	56	N/A	N/A	444	60	4 (1-14)	2 (0-11)

Table 2. Mean fish length, maximum voltage gradient, percent spinal injury and mortality (95% confidence limits in parentheses) for waveforms used in the heterogeneous field experiment conducted August 1, 1991 at the Fort Richardson Hatchery, Anchorage, Alaska.

Waveform	n	Fish length (mm) mean	Fish length (mm) SD	Voltage gradient (V/cm) maximum	Voltage gradient (V/cm) SD	Spinal injury (%)	Mortality (%)
PDC 60/5	12	389	39	2.60	0.70	67 (35-90)	8 (1-38)
PDC 30/5	12	398	28	4.36	1.48	33 (10-65)	33 (10-65)
PDC 20/7	12	421	59	5.82	1.98	25 (6-58)	17 (3-48)
PDC 20/2	12	405	41	1.53	0.70	58 (28-85)	25 (6-58)
DC	12	400	30	9.01	2.51	17 (3-48)	0 (0-27)
CPS	12	382	44	0.44	0.12	8 (1-38)	8 (1-38)

Discussion

Spinal injury rates due to exposure to both the homogeneous and heterogeneous electrical fields were similar. PDC generally caused high rates of spinal injury, 25-75%, while DC and CPS™ caused relatively low injury rates, 8-33% (Tables 1 and 2). The results for PDC were similar to the studies of Sharber and Carothers (1988) and Holmes et al. (1990) where spinal injury rates ranged from 41-67%. The PDC waveforms with a low frequency and high duty cycle tended to have lower, but unacceptable, rates of spinal injury.

Internal hemorrhage rates for all waveforms tested in the homogeneous field experiment were not significantly different and there was little or no correlation between internal hemorrhage and spinal injury. It would appear that spinal injury and internal hemorrhage are not directly related and could occur independently of each other, though a larger sample size for each waveform might be more conclusive.

Despite a significant difference in mean lengths among treatments in the homogeneous field experiment, there was no difference in mean lengths between injured and uninjured fish within treatments. The same was true for the heterogeneous field experiment and between injured and uninjured fish within treatments. There was also no difference in mean lengths among shocked-injured, shocked-uninjured, and control fish in the long-term mortality experiment. Although larger fish are reported to be more sensitive to electrical fields (Sullivan 1956), no such length bias occurred in my experiments.

No significant differences occurred in mortality rates between waveforms in the heterogeneous field experiment, though three waveforms gave mortalities above 10%, which probably would not be acceptable for most mark-recapture studies. PDC 60/50 caused 34% mortality in the long-term mortality experiment, which used a homogeneous field and a sample size over 8 times greater than that of the heterogeneous field experiment in which the same waveform caused 8% mortality. Though there was no significant difference in injury rates between homogeneous and heterogeneous electrical fields, there was a trend for lower injury from the heterogeneous field. This could be explained by the fact that a fish has no chance of escaping to a lower voltage gradient in a homogeneous field because the field is uniform. In a heterogeneous field the fish could escape or it's momentum could move it to a lower voltage gradient. Holmes et. al. (1990) had reported 14% short-term mortality in large rainbow trout captured with

PDC 60/50, which is similar to the results of the heterogeneous field experiment.

Another concern in the mortality results is how these results apply to wild rainbow trout. An injured trout in a hatchery is more likely to survive than a wild trout which must face its environment, avoid predators, and capture prey. One might expect that mortality rates among shocked fish in a wild population would be higher. Mesa and Schreck (1989) reported wild cutthroat trout appeared to be more severely affected (decreased rates of feeding and aggression) after capture by electrofishing and took longer to regain normal behavior than hatchery fish. A controlled, long-term electrofishing study of mortality in wild rainbow trout would be difficult; holding pens would cause additional stress that could increase mortality. An ideal study situation would occur in a small lake with an adequate food supply, that could be monitored for mortalities and enable all fish to be collected or accounted for at the end of the experiment.

In all control and field trial experiments at least half of the spinal injuries were rating 2 for each waveform. There was no difference in mortality among ratings, suggesting that the severity of the spinal injury does not affect survival of rainbow trout. The rating system developed for this project was arbitrarily set to identify different injuries, and may not accurately reflect severity of injury. There was only one rating 3 injury in the long-term mortality experiment and that fish was still alive after 203 days. The lack of rating 3 injuries in both the hatchery and field experiments may indicate that severe spinal injuries in rainbow trout captured with these waveforms and under these water conditions are unlikely.

Eighty-three percent of the mortalities occurred within 30 days after shocking; 78% of these occurred between 8 and 27 days after shocking. Therefore, any study involving recapture of electrofished rainbow trout should occur within 7 days of the initial sampling period or the estimates could be severely biased. Future studies of electrofishing mortality to rainbow should be at least 30 days in length. This could be difficult in field experiments because other factors could affect survival of wild fish held in pens, such as the stress of crowding and inadequate water flow.

The high rate of mortality in shocked-injured fish (52%) could reflect mortality from spinal injury, but shocked-uninjured fish had 29% mortality and spinal injury was not determined in these fish. There was no significant difference between these mortality levels. This may indicate that other physiological effects caused by electroshocking are just as important a concern in causing mortality as spinal injury. A combination of physiological and environmental factors as a source of mortality in rainbow trout has been discussed in other literature (Schreck et al. 1976). Further study into other physiological injuries caused by electrofishing is necessary, but until these studies are conducted long-term mortality after electrofishing would be the best measure of the effects of an electrofishing waveform.

Electrofishing had no effect on growth in both the long-term mortality experiments (homogeneous and heterogeneous fields). The results could be different in a wild population, where an injury could influence a fish's ability to capture food.

In the field trials, results were variable for DC. Why the injury rates were variable is unclear. Fifty-five percent of the X-rays for DC in trial two were unreadable, but the unreadable X-rays should have occurred randomly and not highly biased the injury rate. Mortality rates were also variable for DC between the two trials. The low P value (0.1366) in the test comparing capture rates of DC and CPS™, suggest that the capture rate for DC would have been significantly higher, if sample size had been larger. CPS™ had the second lowest injury rate and lowest mortality rate, and appeared to have the least "stunning" power of the three waveforms (personal observation). Injury rate for DC in the second trial was similar to that for CPS™. In the first trial DC gave capture rates similar to the second trial, but unacceptable injury and mortality rates. PDC 25/75 had the highest injury and mortality rates and is clearly unacceptable for use on rainbow trout, though the capture rates were similar to DC. There was no difference in mean lengths of rainbow trout captured with DC or PDC 25/75, but fish captured with CPS™ were significantly larger than DC. This would indicate that CPS™ is biased towards capturing larger fish. The results of this experiment would lead to the use of CPS™ on rainbow trout, were it not for unacceptably low capture rate and tendency to capture larger fish. However, variable results in injury and mortality for DC, combined with the high capture rates, indicates a need for further testing of DC as a means to capture rainbow trout.

A recommendation from the results of these experiments would be further testing of the DC and CPS™ waveforms. Field trials comparing the two waveforms are necessary to: (1) determine actual injury rates of DC; (2) verify the high capture rates of DC and low capture rates of CPS™; (3) verify the low injury and mortality rates of CPS™ and low mortality of DC. Experiments designed to answer these questions should be conducted at a site that provides: (1) high density of rainbow trout, to allow for sample sizes of 70 fish or greater per waveform (90% level of confidence; Zar 1984); (2) a river segment sufficiently long to allow for at least 5 replicates per waveform with no repeatable passes, and progress upstream so the likelihood of capturing previously injured fish is low; and (3) a river system that has no history of electrofishing.

Fisheries biologists and workers must be concerned with the effects the method of collection has on the fish population and possible sampling bias to the results. In mark-recapture studies, concern of reduced catchability of fish in subsequent captures should not be overlooked (Cross and Stott 1975). If electrofishing is the method of capture, a waveform that has low injury and mortality rates is desired. In large rainbow trout, pulsed DC causes injury and mortality rates that could bias results and affect the fish population; DC and CPS™ may be acceptable alternatives, depending on study objectives and sampling requirements.

The results from the above experiments were conducted at lower water conductivities (30-121 µS/cm), and may not be applicable to systems with higher conductivity. The species that is sought should also be of concern to fisheries workers. Injury rates of 3-62%, (depending on river system) have been reported for Arctic grayling *Thymallus arcticus*, less than 5% spinal injury for least cisco *Coregonus sardinella*, and humpback whitefish *Coregonus pidschian*, and nearly 16% for northern pike *Esox lucius*, all captured with PDC 60/50 (Holmes et al. 1990). The variability in injury rates in species from a single waveform must be kept in mind when electrofishing in a system where many species exist. A waveform or method that will provide acceptable catch rates with the least injury to all species should be used.

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