North American Journal of Fisheries Management 15:799–803, 1995

Influence of Pulsed Direct Current Electrofishing on Mortality and Injuries among Four Centrarchid Species

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Abstract.—The effects of pulsed direct current electrofishing on mortality of and injury to largemouth bass *Micropterus salmoides*, smallmouth bass *M. dolomieu*, bluegill *Lepomis macrochirus*, and pumpkinseed *L. gibbosus* were examined. The pulse frequencies were 30, 60, and 120 Hz, and conductivity categories of 122–214, 456–683, and 752–789 μS/cm were used. Three independent collections were made with nine different combinations of pulse frequency and range of conductivity. Fish were placed in holding pens for 72 h; dead fish were removed and autopsied immediately. Internal hemorrhages were documented by dissection; potential skeletal damage was determined by radiography. After 72 h, one-fourth of the caged fish were sacrificed and examined for internal hemorrhages. Of 454 largemouth bass collected, 6 died (1.3%) and another suffered external injury. Of 145 smallmouth bass, 1 died (0.7%) and another 5 (3.4%) exhibited external injuries. Of 568 bluegills, 30 died (5.3%). Fifty-five pumpkinseeds were examined and none died or were injured. Pulsed direct current electrofishing did not cause high mortality; none of the X-rayed fish exhibited skeletal damage. Mortality appeared to be caused by hemorrhages of the dorsal aorta and other nearby blood vessels in the caudal area.

Electrofishing is commonly used to capture freshwater fish and is often used in the study of fish populations (Steinmetz 1990). Although its effectiveness is limited to shallow waters (Reynolds 1983), generally a large sample is captured (Cowx et al. 1990) that is representative of the overall population (Santucci and Wahl 1991). Initially, alternating (AC) current was widely used (Everhart and Youngs 1953), but more recently, direct (DC) current has been used in waters with conductivity less than 1,000 μS/cm (Cowx et al. 1990).

Electrofishing seriously injures and kills rainbow trout *Oncorhynchus mykiss* and other salmonid species (Hauck 1949; Pratt 1955; Hudy 1985; Reynolds and Kolz 1988; Sharber and Carothers 1988), and use of this technique might seriously compromise any study of populations. Sharber and Carothers (1988, 1990) reported that 50% of rainbow trout and brook trout *Salvelinus fontinalis* had spinal injuries associated with pulsed direct current (PDC) electrofishing. Spencer (1967) found that 1.5% of bluegills *Lepomis macrochirus* and 12.2% of largemouth bass *Micropterus salmoides* suffered vertebral damage with AC electrofishing, and Schneider (1992), also using AC, found lower mortality for centrarchids than did Spencer (1967). Pulsed direct current electrofishing is used in Illinois waters with low conductivities and is frequently used for sampling various populations of centrarchids. To our knowledge, no study had been conducted on mortality and injury to centrarchids collected by PDC electrofishing.

We examined the impact of PDC on mortality of and injury to largemouth bass, smallmouth bass *M. dolomieu*, bluegills, and pumpkinseeds *L. gibbosus* at three pulse frequencies and three ranges of water conductivity. The objective of the study was to determine the extent of injury and mortality caused by PDC electrofishing for these species.

Methods

We collected all fish by PDC electrofishing in three freshwater lakes in Illinois and in Diversey, Belmont, and Jackson Park harbors on Lake Michigan in Chicago from May 7 to August 22, 1990. Three pulse frequencies were used to collect fish: 30, 60, and 120 Hz; the wave shapes were fast-rising and slow-falling. Output current was 2–25 A, depending on conductivity. For each collection, pulse frequency, output amperage, water conductivity, and water temperature were recorded. Conductivities were measured to the nearest 1 μS/cm.

Water conductivities were classified as low (122–214), intermediate (456–683), and high (752–789 μS/cm). There were nine treatments: three pulse frequencies within the three ranges of

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TABLE 1.—Numbers and sizes of centrarchids examined and affected by pulsed direct current electrofishing. Mean total length (cm) and standard deviation are in parentheses; if the number of dead or injured fish is fewer than three, only the total lengths are shown.

Species	Number shocked	Number dead	Number obviously injured	Number cryptically injured/number subsampled
Largemouth bass	454 (20.8 ± 10.4)	6 (16.6 ± 2.2)	1 (17.0)	2/114 (16.6, 17.1)
Smallmouth bass	145 (21.1 ± 12.8)	1 (12.1)	5 (15.3 ± 3.4)	4/29 (14.4 ± 1.8)
Bluegill	568 (13.2 ± 8.1)	30 (8.7 ± 2.4)	0	0/142
Pumpkinseed	55 (11.1 ± 3.9)	0	0	0/14

conductivity. Three independent collections were taken for each treatment for a total of 27 samples.

The electrofishing equipment consisted of a 5.5-m aluminum-hulled boat and a Smith–Root Model 5.0 GPP AC–DC electrofishing unit powered by a 230-V generator. It had Wisconsin-type rings with droppers attached to each boom.

Two netters collected and placed fish in a 1,514-L tub of water. Fish were sampled at night near shore as the boat moved at a rate of approximately 0.5 m/s for 1 h. The total length of each fish was recorded.

Fish were held for 72 h in cages 1.22 × 1.22 × 1.22 m covered by 0.6-cm rigid monofilament plastic netting. Cages were checked twice daily, and dead fish were removed. After 72 h, fish were examined for external damage. All dead fish and those with severe external injuries were autopsied for hemorrhaging and X-rayed for skeletal damage. In addition, 25% of the surviving caged fish were selected at random and sacrificed and examined by autopsy for internal injury. The remaining caged fish were released.

Skeletal damage was examined by dissection and X-ray radiographs taken at Loyola University Medical Center in Maywood, Illinois. Lateral views were taken, and external markings, dark bands, and flesh avulsions were noted.

A logistic regression model and multiple-regression analyses were used to test whether particular pulse frequencies or combinations of pulse frequency and conductivity and other environmental and biological variables were significantly associated with the mortalities of the four centrarchid species (Zar 1974).

Results

Of 454 largemouth bass caged, 1 was observed with external damage and 6 others (1.3%) died in the cage (Table 1). The fish with external damage had a dark vertical band 55 mm long on its side. The skin was slightly avulsed and contained clotted blood. This fish recovered well in 72 h, but because of the external damage, was sacrificed. When autopsied, only local hemorrhaging and ecchymosis were associated with the avulsed area. The dead fish had extensive soft tissue damage. The main site of damage was the dorsal aorta and other blood vessels in the caudal peduncle. Plane radiographs depicted no skeletal damage, although subluxations, (partial dislocations) between vertebrae occurred (Appendix). Of 114 caged largemouth bass subsampled, two had pale ecchymoses midlaterally in the caudal area. No internal damage of either soft or hard tissue was observed among the subsampled fish.

Of 145 smallmouth bass caged, only 1 (0.7%) died in the cage (Table 1). An autopsy revealed minor hemorrhaging from the dorsal aorta and other blood vessels in the caudal peduncle. Five additional smallmouth bass exhibited external soft tissue damage and internal hemorrhaging at the same location. Of 29 caged fish subsampled, 4 exhibited internal damage at the same location. They also exhibited external ecchymoses midlaterally in the caudal peduncle. Radiographs revealed no skeletal damage to any dead or injured fish (Appendix).

Of 568 bluegills caged, 30 (5.3%) died. The injuries were soft tissue damage with internal hemorrhaging of the dorsal aorta and other blood vessels from the middorsal fin to the caudal area. There was external ecchymosis midlaterally in the caudal peduncle. No skeletal damage was found in the dead fish, although one bluegill exhibited a subluxation between vertebrae (Appendix). The subsample of 142 fish were autopsied, but no injuries were detected.

Of 55 pumpkinseeds caged, none died or showed obvious injury. A subsample of 14 pumpkinseeds were autopsied and showed neither soft nor hard tissue damage.

Logistic regression analysis indicated that pulse frequency and conductivity did not independently affect fish mortality: P = 0.07 for largemouth bass, 0.824 for smallmouth bass, 0.157 for bluegills, and

1.0 for pumpkinseeds. Multiple-regression analysis showed that pulse frequencies and conductivities did not interactively affect mortality significantly ($P > 0.05$). Fish length, date of collection, and lake of collection were not significantly associated with fish mortality ($P > 0.05$). However, mortality was so low that smaller fish appeared to be more affected by PDC than larger ones, but the sample size (dead fish) was probably too small to indicate if fish length or other variables were significantly related to fish mortality.

Discussion

Sharber and Carothers (1988) were able to distinguish between old spinal injuries and recent ones. We found no evidence of spinal fractures among dead or injured fish and assumed that skeletal damage would be small within the natural fish populations, but we could not independently assess that assumption. To use the same electrofishing gear but not a current and still collect fish is virtually impossible. The lakes with conductivities less than 1,000 μS/cm were deep, and seining was not possible. Indeed, use of seines would not necessarily indicate damage existing in a natural population because seining could cause some mortality and hemorrhaging. Only by using an entirely different collecting method could one compare the harm, including spinal damage, that the methods might inflict on fish. Although there were no spinal fractures among the fish we collected by electrofishing, there were some hemorrhages and subluxations apparently caused by electrofishing.

Although PDC electrofishing did kill some fish, mortality was low—approximately 1%, except for 5.3% of bluegills. The smaller bluegills (<10 cm) had the greatest mortality. Theoretically, larger fish should be more sensitive because the head-to-tail potential should be larger (Jesien and Hocutt 1990; Regis et al. 1981). The greater mortality among smaller bluegills might deserve further analysis under controlled conditions. The mortality in this study was similar to that of AC electrofishing found by Spencer (1967) for bluegills and largemouth bass, except there were no spinal fractures, and by Schneider (1992) for these two species and pumpkinseeds. Cowdell and Valdez (1994) found no deaths among 40 roundtail chubs *Gila robusta* but two were hemorrhaging; there was no spinal damage. In most reports of spinal damage in fish, AC electrofishing was used (Hauck 1949; Hudy 1985). Maxfield et al. (1971) found no apparent effect of PDC on fingerling rainbow trout. Horak and Klein (1967) found that swimming performance of rainbow trout was affected by DC electrofishing. Because PDC caused little mortality and was effective at conductivities less than 1,000 μS/cm, it can be used to sample the centrarchids we studied without significantly harming them.

Acknowledgments

We thank Kenneth Stuecheli and Mathew Harp for their help with electrofishing and Gerald Funk for his guidance in the statistical analyses. Funding was provided by the Max McGraw Wildlife Foundation. This research was in partial fulfillment of the requirements for a Master of Science degree. The boat was outfitted by the Illinois Department of Conservation.

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Appendix: Radiological Data

TABLE A.1.—Radiological data for fish that were externally injured (EX), internally injured (IN), or died in the cage (D). Except for one largemouth bass caught by hook and line (HL), all fish were caught by electrofishing. Species are smallmouth bass (SMB), largemouth bass (LMB), and bluegills (BL).

Species	Nature of injury	Observations
SMB	EX	No evidence of spinal fracture, spinal dislocation, or soft tissue damage
LMB	EX	No misalignment of vertebrae or interruption of intervertebral spaces; no evidence of soft tissue damage
SMB	EX	No evidence of spinal fracture, dislocation, misalignment, or soft tissue damage
LMB	HL	No evidence of spinal fracture, dislocation, misalignment, or soft tissue damage; old healed (calloused) rib Fx (17th and 18th ribs); no hematoma
SMB	EX	No evidence of spinal fracture, dislocation, misalignment, or soft tissue damage
LMB	IN	No evidence of spinal fracture, dislocation, misalignment, or soft tissue damage
SMB	EX	No evidence of spinal fracture, dislocation, misalignment, or soft tissue damage
LMB	D	Mild subluxation in 11th and 12th vertebral interspace; multiple scattered soft tissue lucencies
LMB	D	Apparent mild subluxation between 10th and 11th vertebrae; no evidence of fracture
SMB	IN	No evidence of spinal fracture, dislocation, or misalignment; multiple scattered soft tissue lucencies
SMB	IN	No evidence of spinal fracture, dislocation, or misalignment; soft tissue lucencies in craniodorsal region
LMB	D	Significant subluxation at 10th and 11th vertebral space; irregular outline of swim bladder, multiple scattered soft tissue lucencies caudally
SMB	D	No evidence of spinal fracture, dislocation, or misalignment; irregular swim bladder, and caudal soft tissue lucency
LMB	IN	No evidence of spinal fracture, dislocation, or misalignment
LMB	D	Significant subluxation at 10th and 11th vertebral interspace with adjacent irregularity of swim bladder; hematoma silhouette
SMB	IN	No evidence of spinal fracture, dislocation, or misalignment
BL	D	No evidence of spinal fracture, dislocation, or misalignment; caudal and gastric lucencies
BL	D	No evidence of spinal fracture, dislocation, or misalignment; caudal and gastric lucencies
BL	D	No evidence of spinal fracture, dislocation, or misalignment; caudal and gastric lucencies
BL	D	No evidence of spinal fracture, dislocation, or misalignment; some lucencies in soft tissue
BL	D	No evidence of spinal fracture, dislocation, or misalignment
BL	D	No evidence of spinal fracture, dislocation, or misalignment; irregular dorsal border
LMB	D	Significant subluxation and misalignment of 11th and 12th vertebral interspace; caudal and dorsal lucencies; swim bladder distended
LMB	D	Possible subluxation at 8th and 9th vertebral interspace as well as paravertebral hematoma with irregular swim bladder silhouette

TABLE A.1.—Continued.

Species	Nature of injury	Observations
SMB	IN	No evidence of spinal fracture, dislocation, misalignment, or soft tissue damage
SMB	IN	No evidence of spinal fracture, dislocation, misalignment, or soft tissue damage
BL	D	Subluxation between 4th and 5th vertebrae; no evidence of soft tissue damage
BL	D	No evidence of spinal fracture, dislocation, misalignment, or soft tissue damage; swim bladder with irregular border
BL	D	No evidence of spinal fracture, dislocation, misalignment, or soft tissue damage

TABLE A.1.—Continued.

Species	Nature of injury	Observations
BL	D	No evidence of spinal fracture, dislocation, misalignment, or soft tissue damage
BL	D	No evidence of spinal fracture, dislocation, misalignment, or soft tissue damage
BL	D	No evidence of spinal fracture, dislocation, or misalignment
BL	D	No evidence of spinal fracture, dislocation, misalignment, or soft tissue damage; irregular 7-mm spherical density in abdominal region and multiple fractures of anal fin rays, probably old