Increasing the Effectiveness of Electrofishing Boats in Low Conductivity Waters

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Abstract: The anode and cathode arrangements on an electrofishing boat using pulsed D.C. output were manipulated to increase the effective area of the electric field. Voltage gradient (volts/cm) measurements were taken at various distances and depths at 90 and 180 degrees in relation to the long axis of the electrofishing boat. The objective of the study was to improve the efficiency of the electrofisher in low conductivity waters. The maximum distance and depth of field increased an average of 71% and 72%, respectively, for the 2 sample sites when comparing the initial configuration (15-cm anode droppers and a 30-cm side dropper array as the cathode) to the final configuration (30-cm anode droppers and the boat hull with paint removed as the cathode).

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Electrofishing is a primary sampling technique utilized by the North Carolina Wildlife Resources Commission. The effectiveness of the electrofisher is, however, limited by the low conductivity waters (less than 100 umhos/cm) characteristic of many coastal plain river systems. Relatively lower catch rates are obtained when electrofishing in low conductivity water in comparison to those of higher conductivity (100–500 umhos/cm). The effective area of the electric field is limited at low conductivities by the increased resistivity of water and the corresponding decrease in electrode current. A minimum current of 2 amperes and voltage gradient between 0.1 and 1.0 volts/cm is generally required for effective electrofishing (Reynolds 1983). Successful electrofishing with total electrode current less than 2 amperes has, however, been reported in low conductivity waters (Novotny and Priegel 1974). The capture of fish is a function of power density (microwatts/cm^3), the product of voltage gradient and current density. As conductivity decreases, higher voltage gradients are required to achieve effective power densities. To maintain required currents in low conductivity water, it is necessary to modify the electrofishing boat to either increase the applied voltage or increase electrode size. Due to monetary and safety considerations, it is generally more practical to increase electrode size. Increasing the size of the anode to produce a larger "stun" field must be accompanied by corresponding increases in cathode size to maintain greater anode resistance. In effect, increasing cathode size decreases the resistance of the cathode and increases the proportion of the voltage at the anode.

The objective of the study was to improve the efficiency of a pulsed D.C. electrofisher in low conductivity waters by evaluating different electrode arrangements. An arrangement producing a voltage gradient of at least 0.1 volts/cm the greatest distance from the anode was considered optimum. Only pulsed D.C. output was considered due to the reduced potential lethality in comparison to A.C. in low conductivity water.

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Methods

Field sampling was conducted at 2 North Carolina coastal plains lakes with conductivities <100 umhos/cm: Lake Rim (Cumberland Co.) and Sutton Lake (private—Lenoir Co.).

A Tektronix 305 DMM oscilloscope and a Beckman Digital Multimeter with a hand-held probe were used to measure the voltage gradient (volts/cm) produced by an electrofisher (Coffelt VVP-15). The probe consisted of 19-mm PVC pipe marked in 10-cm increments with 5-mm terminals spaced 1 cm apart. The 1-cm spacing of the terminals allowed the direct measurement of the voltage gradient from the volt meter. Pulsed D.C. output with a frequency of 80 pulses per second and a pulse width of 40% (5 milliseconds), as recommended by the manufacturer, were used throughout the study. Output voltages were set at the maximum sustainable level of the electrofisher for each electrode configuration. The electrofishing boat was anchored in water with a minimum depth of 1.8 m and measurements of the field at different distances and depths were taken from a small, fiberglass hulled boat. Measurements were made along a 2.4-m long, 2.5 × 10-cm board that was fastened to the anode ring of the electrofishing boat. A 20-cm section of 5-cm PVC pipe was clamped perpendicular to the board at each test distance as a guide for maintaining the probe in a vertical position. The voltage gradient was measured in 10-cm increments in depth at 30-cm intervals in distance from the anode. At each distance from the anode, the probe was lowered in the water and measurements taken until the depth was reached at which the voltage gradient dropped to <0.1 volts/cm. The probe was rotated during measurements to obtain a maximum voltage reading in the horizontal plane. Voltage gradient profiles were taken at 90 and 180 degrees from the long axis of the boat. The output voltage, current (amperes), water temperature and conductivity were recorded for each test arrangement.

Test configurations consisted of 2 anode dropper lengths (15 and 30 cm) and 2 cathode arrangements (side droppers and various exposures of the hull as the cathode). The anode array consisted of 2 0.9-m diameter EMT conduit rings (13 mm) welded together (resembling a figure 8) with 18 (9 per ring) stainless steel pipe (19 mm) dropper electrodes suspended from it. The side dropper cathode array was comprised of 10 30-cm lengths of stainless steel tubing (19 mm) spaced 30 cm apart (5 per side of boat). The side dropper cathode arrangement was tested initially with 15 and 30-cm anode droppers and then the hull of the 4.9-m aluminum john boat was converted to the cathode. Paint was removed from the hull to the water line in increments of 20% beginning at the stern and tested with 15 and 30-cm anode droppers. All electrode configurations were tested at Sutton Lake while, at Lake Rim, the 15-cm anode droppers were evaluated in combination with a side dropper cathode and 100% hull exposure and the 30-cm anode droppers with the side dropper cathode and 20%, 40%, and 100% hull exposure.

A *t*-test was calculated within levels of hull exposure to compare differences between the mean number of voltage gradient measurements ≥0.1 volts/cm for the 2 anode lengths (Snedecor and Cochran 1967). Simple linear regression between the average number of voltage gradient measurements and percentage hull exposure for the cathode was computed for each anode length to test the hypothesis that rate of increase was statistically different from zero.

Results

The area of the electric field produced by the electrofishing boat, as estimated by the total number of voltage gradient measurements greater than or equal to 0.1 volts/cm increased as the cathode was converted from a side dropper array to using the hull as the cathode (Tables 1, 2). The area of the field subsequently increased as the area of the cathode increased with additional paint removal. The largest field area was measured utilizing 30-cm anode droppers and 100% hull exposure. The increase in field area was observed at the 2 study lakes with both the 15 and 30-cm anode droppers and at both the 90 and 180 degree orientations to the boat. The increase in field area resulted from concurrent increases in depth and distance from the boom. The maximum distance and depth of field increased an average of 71% and 72%, respectively, for the 2 sample sites when comparing the 15-cm anode droppers in conjunction with a side dropper array as the cathode to the 30-cm anode droppers and the boat hull with 100% paint removed as the cathode (Tables 1, 2). A larger field was observed with the 30-cm anode droppers in comparison to the 15-cm droppers, with the exception of the 80% hull exposure at Sutton Lake.

Differences between the mean number of voltage gradient measurements between the 2 anode lengths were not statistically significant using the *t*-test for any of the cathode configurations. The data from Sutton Lake indicate a statistically significant linear regression ($P < 0.01$) between the average number of voltage gra-

Table 1. Summary of voltage gradient and other data for different electrode configurations at Sutton Lake.

Cathode	Side-droppers		20% exposure		40% exposure		60% exposure		80% exposure		100% exposure	
Anode	15 cm	30 cm	15 cm	30 cm	15 cm	30 cm	15 cm	30 cm	15 cm	30 cm	15 cm	30 cm
Max. field distance (cm)												
90° to hull	90	90	90	90	90	120	90	90	90	90	120	120
180° to hull	60	90	90	90	90	120	90	90	90	90	120	150
Max. field depth (cm)												
90° to hull	60	70	60	80	70	90	70	80	80	80	90	100
180° to hull	60	70	70	70	70	100	70	80	80	80	90	110
N of measurements ($\bar{x} \geq 0.1$ volts/cm)												
90° to hull	18.3	21.0	20.7	26.0	21.0	35.7	25.3	28.0	26.7	23.7	37.0	45.0
180° to hull	16.3	21.3	23.3	26.0	23.7	32.7	23.0	27.0	28.7	26.7	38.3	50.0
Conductivity (μmhos/cm)	90	90	95	95	80	78	90	90	89	89	90	90
Temperature (°C)	11.5	11.5	13.0	13.0	4.8	4.5	12.0	12.0	11.0	11.0	11.5	11.5
Output voltage	330	330	330	330	350	350	350	330	350	310	350	310
Output amperage	3.7	4.2	4.2	5.5	4.0	5.0	4.6	6.5	4.8	6.0	5.0	6.5

Table 2. Summary of voltage gradient and other data for different electrode configurations at Lake Rim.

Cathode	Side-droppers		20% exposure		40% exposure		100% exposure	
Anode	15 cm	30 cm	15 cm	30 cm	15 cm	30 cm	15 cm	30 cm
Max. field distance (cm)								
90° to hull	90	90		120		120	120	120
180° to hull	90	90		150		120	120	150
Max. field depth (cm)								
90° to hull	60	70		90		100	90	110
180° to hull	70	70		90		110	100	110
N measurements ($\bar{x} \geq 0.1$ volts/cm)								
90° to hull	18.7	25.3		34.7		39.7	37.3	47.0
180° to hull	22.7	26.0		41.0		45.7	39.0	56.3
Conductivity (μmhos/cm)	12	12		12		11	11	11
Temperature (°C)	12.0	12.0		8.2		7.2	9.8	9.8
Output voltage	400	400		400		400	400	400
Output amperage	1.0	1.0		1.0		1.0	1.0	1.2

dient measurements $\geqslant$0.1 volts/cm and percentage of hull exposure for the 15-cm anode droppers. While it is possible that the functional relationship is really curvilinear, a lack of fit test failed to detect significant residual after removing the linear component of variance. Statistically significant regressions were not detected for the 30-cm anode droppers at the 2 study lakes. Linear regression analysis was not possible for the 15-cm data from Lake Rim due to inadequate number of data points.

Voltage gradient measurements were highest near the anode and decreased with increasing distance and depth. Maximum depth of field was found within 60 cm of the anode and the field subsequently became more shallow as distance from the anode increased. Higher voltage gradients were measured proximal to the anode with the 15-cm droppers in comparison to the 30-cm droppers. Voltage gradients adjacent to the anode ranged from 1.0 to 2.0 volts/cm ($\bar{x}$ = 1.4) to the side of the boom and from 0.5 to 0.7 volts/cm ($\bar{x}$ = 0.6) to the front using 15-cm droppers at Sutton Lake. Voltage gradients using 30-cm droppers ranged from 0.4 to 1.0 volts/cm ($\bar{x}$ = 0.6) and 0.5 to 0.7 volts/cm ($\bar{x}$ = 0.6) to the side and front of the boom, respectively. The increase in voltage gradient observed close to the anode with the 15-cm droppers decreased rapidly within 20 to 30 cm of the anode to levels comparable to those found with the 30-cm droppers.

Output amperage increased concurrently with the increase in electrode size at Lake Sutton (Table 1). At Lake Rim, with much lower conductivities, the increase in current was not detected except for the 30-cm anode droppers and with 100% of the hull exposed.

Discussion

Study results indicate that increasing anode length and the area of the cathode can increase the area of the electric field and produce a more effective current distribution. The increase in voltage and current density can potentially improve the effective range of an electrofisher using D.C. output in low conductivity waters. Relatively higher voltage gradients are required at low conductivities to obtain power densities of sufficient magnitude to capture fish. A minimum voltage gradient of about 0.5 volts/cm is required at 100 umhos/cm conductivity. The area of the field with voltage gradients greater than 0.5 volts/cm increased after converting the hull to the cathode and should allow the capture of fish at greater distances and depths from the anode. Fish were collected at Lake Rim with the electrofishing boat after modifications at conductivities between 11 and 12 umhos/cm, whereas, previous efforts had been unsuccessful. While some benefit was observed by only increasing anode dropper length from 15 to 30 cm, maximum increase in field range and area were obtained by converting the cathode from a side dropper array to using the hull as the cathode. The increase in cathode area results in a decrease in cathode resistance and increases the percentage of power at the anode. The reduction in resistance with larger electrodes also resulted in increased electrode current. To maintain voltages at higher conductivities it is necessary to reduce anode exposure by either raising droppers or placing insulated sleeves, such as rubber tubing, over the droppers. Novotny and Priegel (1974) recommended for safety reasons that metal boat hulls not be used as either the anode or cathode and that electrodes should be electrically isolated from the hull. Current is, however, conducted through a metal hull even when it is isolated from the electrodes. The potential risk associated with using the hull as the anode is, therefore, no greater than with the hull electrically isolated. All metal parts and equipment such as gas cans, electrofisher, fish tanks, motor, and generator within the boat should be properly grounded, regardless of electrode array.

The voltage gradient measurements obtained during the study are probably less than those actually present within the water, as volt meter readings taken in a pulsed D.C. field represent average voltage values. Voltage gradients are measured with greater accuracy with an oscilloscope. The cause of measurement inconsistencies of voltage gradients with certain electrode configurations is unknown but is probably not attributable to changes in water temperature and conductivity. The failure to detect significant regressions between the average number of voltage gradient measurements ≥ 0.1 volts/cm and percentage of hull exposure for the 30 cm anode droppers was likely a function of high measurement variability. Maximum voltage gradients adjacent to the anode droppers were 1.0 and 2.0 volts/cm for the 15 and 30-cm droppers, respectively. These values, even if actually somewhat higher due to averaging by the volt meter, are below the level at which injury or mortality of fish should result. Field area and voltage gradients were generally comparable between the front and side of the anode rings, indicating that electrofishing is likely to be equally effective with either of these boat orientations.

Literature Cited

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