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[Note]

Boat Electrofishing Relative to Anode Arrangement

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Abstract.—We assessed the effect of boom (i.e., anode) arrangement (a single boom and double booms spaced 1.3, 1.9, and 3.2 m apart) on the characteristics of the electric field formed ahead of an electrofishing boat as well as on fish catch. Anode arrangement affected the lengthwise and crosswise characteristics of the field. As a general rule, rearranging the anodes from a single boom located centrally to a double-boom system with broadly separated anodes shifted the strength of the field outward (away from the center) and forward (away from the boat). The highest voltage gradients occurred when the anodes had the greatest separation. Catch rates varied by boom arrangement, increasing as boom separation increased. Differences in species and length selectivity with respect to boom arrangement were minor. We suggest that the double-boom arrangement with the booms placed about 1.9 m apart (but no more than about 2.5 m) is suitable for most electrofishing applications.

Electrofishing is debatably the most common fish collection method in the freshwaters of North America. The appeal of electrofishing as a collection tool is derived from its ability to provide adequate samples of selected fish species over a broad range of shallow-water habitats. Boat electrofishing is often conducted with a flat-bottom metal boat rigged with an electrode system that produces an electric field ahead of the boat so that fish may be immobilized and collected from the bow. The electrode system commonly consists of one cathode and one or two anodes, the boat hull serving as the cathode. The anodes are suspended from booms extending forward from the bow. The distance between the tip of a boom and the hull of the boat, and the separation between paired booms, affect the shape and strength of the electric field formed ahead of the boat (Reynolds 1996).

Standardization of boat electrofishing is often desired to ensure that stock assessment is consistent and that data collected over time and space are not influenced by differences in gear or gear application. Recently, efforts to standardize electrofishing have focused on adjusting power output so that the power transferred to fish in waters with differing conductivities remains reasonably stable (Kolz and Reynolds 1989; Burkhardt and Gutreuter 1995; Miranda 2005). An aspect of boat electrofishing that has received little or no attention is electrode arrangement. In many boat electrofishers the distance between the hull and the tip of the booms is fixed to prevent direct contact between the anode and cathode during normal operation, but the distance separating double booms is adjustable. Conceivably, boom arrangement can affect field shape and strength and therefore catch rate and catch composition. The objective of this study was to assess the effect of boom arrangement on the characteristics of the electric field formed ahead of an electrofishing boat, and on fish catch.

Methods

A boat electrofisher system similar to that described by Reynolds (1996) was used. The 5.5-m-long, 1.8-m-wide boat had a flat-bottom aluminum hull. It was equipped with two booms mounted at each corner of the bow on swiveling clutches. The clutches allowed the booms to be adjusted vertically and crosswise, but not lengthwise. Each boom was 2.4 m long, and at the end supported an anode array 0.9 m in diameter. The array consisted of six droppers, each 0.5 cm in diameter and 1 m long, spaced evenly around the perimeter. The boat hull served as the cathode. When one dipnetter stood on the bow, the distance between the foremost waterline of the hull and center of anode was about 2.8 m depending on boom separation, and the droppers penetrated 0.8 m into the water. A Smith-Root GPP 7.5 system provided electric power.

The effect of boom separation was assessed by manipulating the position of the booms. Four treatments were considered including a single boom centered in front of the bow, and two booms separated to produce tip-to-tip distances (i.e., distance between booms measured between the two ends) of 1.3, 1.9, and 3.2 m (50, 75, and 125 in). Because of the

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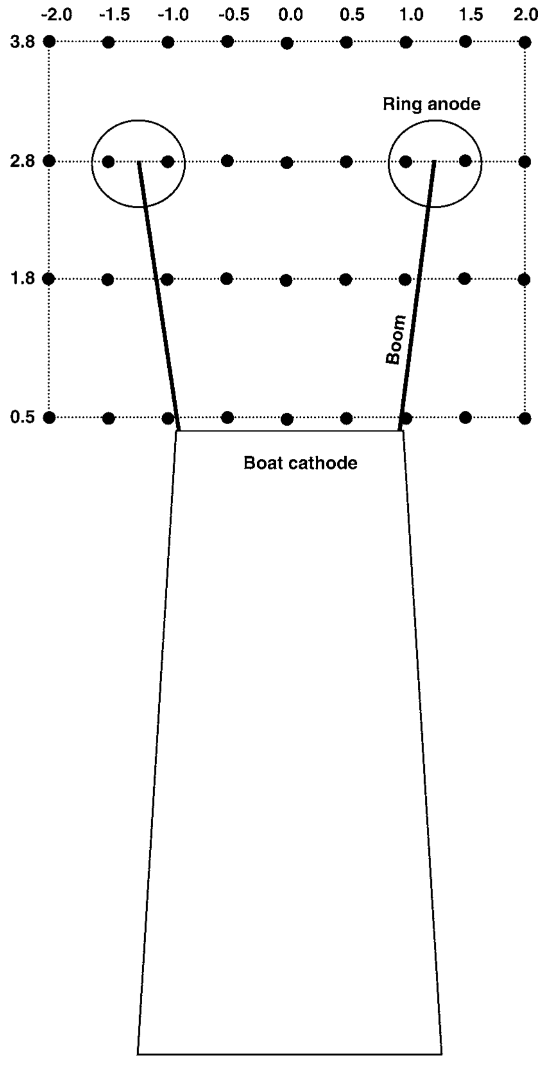

FIGURE 1.—Diagrammatic representation of an electrofishing boat showing the position of the grid and the sampling locations (small solid circles) within the grid. Measurements were made with a single boom positioned so that the anode would be centered in front of the boat and with two booms separated by 1.3, 1.9, and 3.2 m at the tips. The vertical scale represents distances (m) measured frontward from the water line formed next to the hull of the boat; the horizontal scale represents distances measured to the right (positive values) and left (negative values) of the longitudinal axis of the boat.

impracticality of fully mapping voltage gradient over a three-dimensional electrofishing field, we used a grid positioned at the water surface (Figure 1) to sample 36 reference points within a two-dimensional plane located at 30 cm depth. The grid, which was constructed of light lumber, was floated under the booms with Styrofoam floats that did not interfere with the electric field. Points were sampled along four grid transects positioned crosswise to the longitudinal axis of the boat at 0.5, 1.8, 2.8, and 3.8 m from the waterline at the hull of the boat. Measurements were distributed 0.5 m apart within each transect and made with an insulated probe that had two wires extending 0.5 cm past the end of the probe, set 1 cm apart, with insulation removed at the tips to expose about 1–2 mm of bare wire (described by Kolz 1993). At each sample point the probe was submerged to 30 cm below the surface, and rotated 360° to find and record the maximum peak voltage gradient. The probe was attached to a paint roller pin (available at most hardware stores) that allowed rotation to find the maximum voltage gradient, and the roller tool was attached to an extension pole that facilitated reaching the sample point in the grid. The probe was connected to a Tektronix THS720A oscilloscope (Tektronix, Inc., Beaverton, Oregon). As needed, weight was added to the boat to maintain the typical draft and therefore normal positioning of the electrodes.

Each of the four test anode arrangements resulted in a different electrical load. As a result, rearranging the position of the booms without adjusting the output settings produced different levels of power. Therefore, the power applied to the electric field by the electrofishing boat was standardized to 2,900–3,000 W (Miranda 2005), measured as the product of output peak voltage and amperage. Peak voltage was recorded with a Tektronix THS720A oscilloscope and amperage with a Tektronix A622 current probe fitted to the oscilloscope. Power was adjusted to the standard each time the booms were rearranged. Electrofishing was conducted with 60-Hz pulsed DC; pulse width and duty cycle could not be standardized because in the Smith-Root GPP 7.5 unit, pulse width is linked to voltage (Miranda and Spencer 2005).

Fish collection with these four arrangements was evaluated in 220-ha Oktibbeha County Lake, Mississippi, in November 2006. Electrofishing was conducted by steering the boat at slow speed perpendicularly towards shore, and energizing the field within 5–6 m from shore. The field was energized for 10 s, and all the fish surfacing within the 10-s period and 30–60 s after the field was de-energized were dipnetted and placed in a live well. Fish catches were recorded according to species groups and length-groups (<10, 10–20, and >20 cm), and released. Each of the four boom arrangements (i.e., treatments) was replicated 30 times, for a total of 120 samples. For logistical reasons, the 30 samples for each treatment were collected sequentially, and when finished the anode arrangement was adjusted for the next treatment. The order in which the treatments were applied was selected with simple random sampling, and the 30 sites sampled were selected with systematic random sampling from the entire shoreline of the lake excluding the dam. Due to the length of available shoreline (8.9 km), and in view that a sample only encompassed a few meters of shoreline, each sample site was electrofished only once. All sampling was completed within a 2-d period.

Fish data were analyzed to test for differences in catch rate, species composition, and length-group composition over the four boom arrangements. Testing was conducted with analysis of similarities (ANOSIM), a permutation-based nonparametric procedure analog to analysis of variance (ANOVA), which, unlike ANOVA, makes no assumptions about the distribution of the data (Clarke and Gorley 2006). The ANOSIM procedure with 100,000 permutations compared the variability of distributions within boom arrangements against the variability between boom arrangements to assess significance. Three separate analyses were conducted. The first was a one-way design in which boom arrangement represented the treatments and the fish counts in each sample (regardless of size or species) represented the replicates (i.e., four treatments with 30 replicates per treatment). The second was a two-way crossed design with boom arrangement as the treatments and the fish counts in each sample blocked by species (i.e., four treatments with several species and 30 replicates per treatment). The third was also a two-way crossed design with boom arrangement as treatments, and the fish counts in each sample blocked by length-group (i.e., four treatments, three length-groups, and 30 replicates per treatment). Statistical significance was relaxed a priori to $P = 0.10$ to reduce the chance of a type II error (i.e., concluding there is no treatment effect when in fact there is), which we considered to be justified given that adjusting boom positioning usually does not involve major expense or sacrifice and that therefore even small increases in collection efficiency are beneficial.

Results

The voltage gradient profiles differed among boom arrangements and, as expected, they were always higher near the electrodes. The single boom produced the strongest gradients underneath the anode, peaking in front of the boat and gradually diminishing away from the central axis (Figure 2). Along the central axis of the boat the field intensity dropped between the anode and the cathode, increasing near the boat. Many fish immobilized with this arrangement surfaced next to or under the boat, probably due to the high field intensities occurring near the boat. The strength of the voltage gradient created by the 1.3-m boom separation arrangement was greatest underneath the anodes (Figure 2), which was somewhat higher than the single-boom arrangement, and decreased farther away from the anodes. Voltage gradient decreased towards the cathode, reached a minimum, and showed an increase near the cathode as noted for the single-boom arrangement. For the 1.9-m boom separation arrangement, voltage gradient peaked between 0.5 and 1.5 m away from the center under the anodes. Like the 1.3-m boom arrangement, voltage gradient of the 1.9-m boom arrangement decreased toward the cathode and was strongest away from the center. The 3.2-m boom arrangement exhibited the highest voltage gradients, within 1 and 2 m away from the center. Both the 1.9- and 3.2-m arrangements exhibited a steep voltage gradient decrease in the direction of the boat, with a slight increase near the boat. In general, increased separation of the booms increased localized voltage gradient, shifted the strength of the field away from the central axis, reduced field strength between the booms, and reduced field strength near the bow.

In all, 819 fish from 12 species were collected. Five of the 120 samples recorded zero catches; the remaining samples recorded catches ranging from 1 to 27 fish per sample with a median of six fish. The most common species were bluegill *Lepomis macrochirus* ($n = 472$), redear sunfish *L. microlophus* ($n = 108$), gizzard shad *Dorosoma cepedianum* ($n = 94$), white crappie *Pomoxis annularis* ($n = 86$), largemouth bass *Micropterus salmoides* ($n = 29$), and black crappie *P. nigromaculatus* ($n = 10$). The most abundant size-group was 10–20 cm ($n = 587$), followed by those greater than 20 cm ($n = 130$) and less than 10 cm ($n = 102$).

Catch rates differed over boom arrangements ($P < 0.01$). The single boom, and the 1.3-m, 1.9-m, and 3.2-m boom separations caught an average of 4.0 (range = 0–9), 6.8 (range = 0–14), 7.8 (range = 0–27), and 8.7 (range = 1–25) fish per sample, respectively. The ANOSIM procedure indicated that differences in catch rates were statistically significant between the single boom and all the double-boom arrangements ($P < 0.04$). Additionally, catch rates differed significantly between the 1.3-m and 3.2-m boom arrangements ($P = 0.03$) and between the 1.3-m and the 1.9-m arrangements ($P = 0.08$). Catch rates did not differ between the 1.9-m and 3.2-m boom arrangements ($P = 0.19$).

Differences in species and length selectivity over boom arrangements were minor. Testing for differences in species composition was restricted to the common species listed previously, with crappie species combined. The ANOSIM indicated that species selectivity did not differ over boom arrangements ($P = 0.61$). Length distribution over boom arrangements were

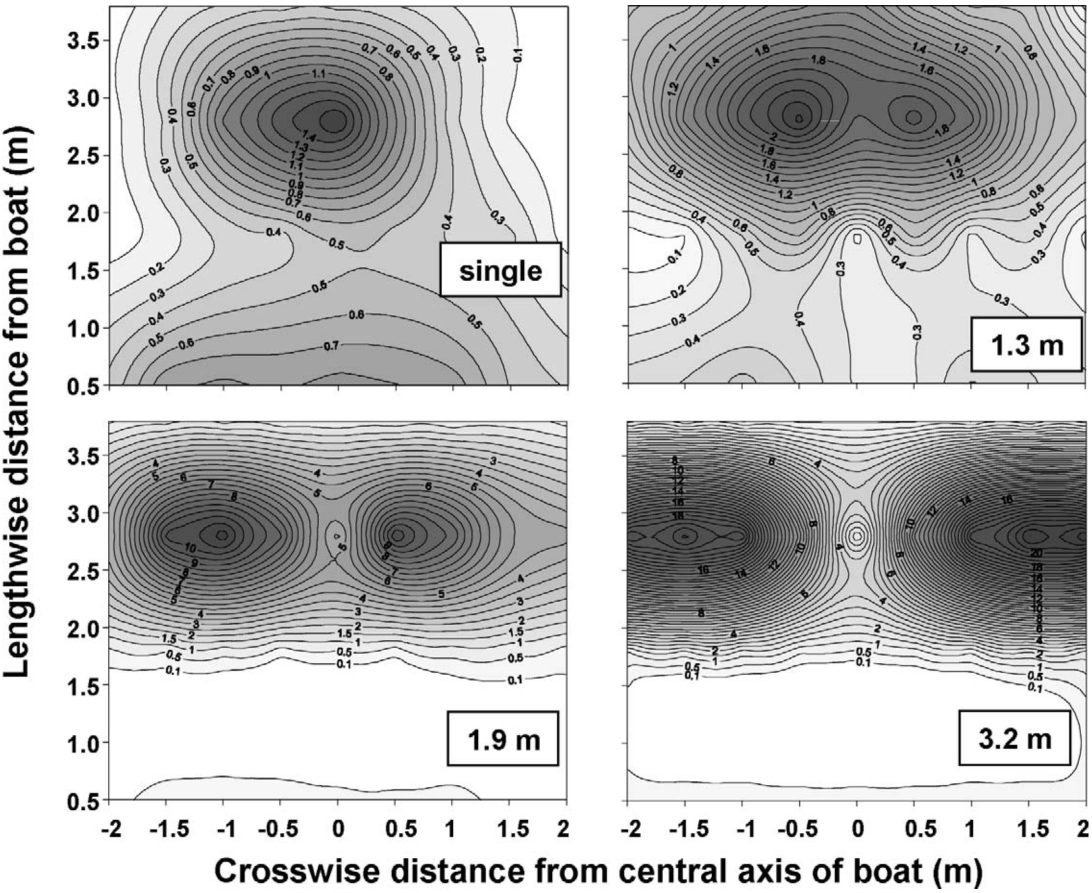

FIGURE 2.—Voltage gradients for the test boom arrangements (a single boom and double booms separated by 1.3, 1.9, and 3.2 m) estimated from the sampling sites shown in Figure 1. The vertical scale represents distances (m) measured frontward from the waterline formed next to the hull of the boat; the horizontal scale represents distances measured to the right (positive values) and left (negative values) of the longitudinal axis of the boat. The numbers over the isoclines represent estimated voltage gradients (V/cm); the scales of which differ over the four panels. The electric fields were reconstructed based on the reference points using the kriging method in Surfer software (SSG-Surfer, Sandy, Utah).

marginally significant ($P = 0.10$). The ANOSIM procedure revealed that the length differences were restricted to the most contrasting boom arrangements, the single boom differing from the 3.2-m arrangement ($P = 0.01$). Further examination of this difference revealed that the 3.2-m double-boom arrangement tended to catch proportionally more small fish than the single-boom arrangement. All other length comparisons were not significant ($P \geq 0.12$).

Discussion

Electrode arrangement affected the lengthwise characteristics of the electric field. According to Kolz (1993) the voltage gradient between anode and cathode has a U-shaped profile that is symmetrical when the anode and cathode are identical. An asymmetric U-shaped pattern was evident in all four boom arrangements; the extent of the asymmetry was least in the single-boom arrangement and increased with boom separation in the double-boom arrangements. Invoking Kolz (1993), we suspect that voltage gradient continued to increase near the boat to levels higher than those we detected at the 0.5-m transect. In essence, electrode arrangement shifted the lengthwise voltage gradients between the anode(s) and the cathode.

Electrode arrangement also affected the crosswise characteristics of the electric field. For the single-boom arrangement voltage gradient was strongest in the center. As the arrangement transitioned from a single boom positioned centrally, to a double-boom system with broadly separated anodes, the strength of the field migrated outwards away from the center. The weakest double-boom electrical field was recorded when the anodes were in closest proximity and the strongest when the anodes had the greatest test separation. In close proximity, the electric fields created by the anodes become electrically coupled (Beaumont et al. 2006), decreasing resistance, increasing amperage, reducing voltage, and thus reducing the voltage gradient (L. Kolz, personal communication). Booms in close proximity not only reduce voltage gradient in the vicinity of the anodes, but also, due to increased current demand, can overload the generator (i.e., generator is unable to reach target output). As the booms were spread, the anodes became isolated increasing their resistance and reducing amperage, resulting in increased voltage gradient.

Electrode arrangement also influenced the catch rate and length composition of the catch, but was not species selective. We suspect that the increase in the catch rate as the booms were spread is due to a combination of an increase in the voltage gradient, a widening of the effective immobilization zone (Novotny 1990), and a shift in field strength from under the netter to ahead of the netter. We speculate that differences in length composition may be attributed to differences in capacity to immobilize small fish and the dipnetter's ability to see them. Small fish are more difficult to immobilize with electrofishing than large fish (Dolan and Miranda 2003), and the stronger voltage gradient generated by the 3.2-m arrangement might have increased the electrofisher's ability to immobilize them. Also, the single-boom arrangement tended to immobilize a greater fraction of fish near and under the boat, where small fish might have been less visible to the dipnetter. Nevertheless, the magnitude of differences in species and length composition is likely to differ among water bodies as fish community and fish size compositions vary.

In view of the effects that electrode arrangement can have on electric fields, catch rates, and catch composition, electrofishing sampling programs should standardize electrode arrangement. A major limitation of widely spread boom arrangements is the difficulty in navigating around obstacles, such as trees often found along shore and in the littoral zone. Also, high localized voltage gradients could be lethal to some fish. The 1.3-m-separation arrangement can overload the generator and interfere with the netting because the two booms are positioned immediately ahead of the bow. The single-boom arrangement shifts the voltage gradient too close to the boat, potentially reducing the ability of the dipnetter to notice fish. We suggest that the double-boom arrangement with booms distanced about 1.9 m apart, but no more than about 2.5 m, is suitable for most electrofishing applications in boats with dimensions similar to ours.

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