Electrofishing Raft/Boat Evaluation for the

Grand Canyon Monitoring and Research Center (GCMRC)

March 31 – April 1, 2015

Lee's Ferry Reach, Colorado River

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Evaluations of the electrical output and operations of the Achilles raft and Osprey boat were performed. Purposes were to:

1. Measure electrode resistance of the Achilles and Osprey crafts;
2. Characterize the Achilles and Osprey electrical fields;
3. Estimate maximum electrical output across the water conductivity range encountered in the Grand Canyon for each craft;
4. Estimate electrical outputs required for successful electrofishing sampling across the water conductivity range (generate voltage, amperage, and power goal tables) for each craft;
5. Determine if the generator/control box in each craft can meet required goal outputs given the present electrode design; and
6. Standardize the Achilles and Osprey such that the electrical fields are the same across the water conductivity range.

Analysis of data was performed with the Excel files "Electric Field Mapper and Standardization…", "Boat Power…", and "EF Goal Power…". These files will be supplied to Dave Foster.

Water conditions:

Visibility: clear to a depth of at least 9 feet
Specific water conductivity = 833 µS/cm; water temperature = 9.49 degrees C
Ambient water conductivity = 585 µS/cm

Achilles Raft

The electrode arrangement was one anode 11" sphere on the bow and one cathode 11" sphere aft. The control box was an *MBS-1DPQ-CR-AZ* powered by a 6,500 W generator.

Electrode Resistance

Novotny theoretical resistance at 100 µS/cm for Achilles electrode system = 114 Ohms

Achilles with both spheres fully submerged:

490V, 16.5 I = 29.7 Ohms or 174 Ohms at 100 µS/cm
550 V, 19 I = 28.9 Ohms or 170 Ohms at 100 µS/cm
One 11" sphere = 172/2 = 86 Ohms at 100 µS/cm

Achilles with anode sphere partially submerged (~2" exposed):

520V, 16 I = 32.5 Ohms or 190 Ohms at 100 µS/cm

One 11" sphere = 190-86 = 104 Ohms at 100 µS/cm
Anode = 104 Ohms, cathode = 86 Oms at 100 µS/cm

Electric Field Mapping

The Achilles Raft was moored near-shore with the bow facing the shore. The anode sphere was positioned in about 2.5’ of water with the axis of the raft perpendicular to shore. Measurements were taken at locations distant from the sphere center in a lateral vector (perpendicular to the anode boom).

Applied voltage: 522 V
Applied current: 16.5 – 17.0 amps

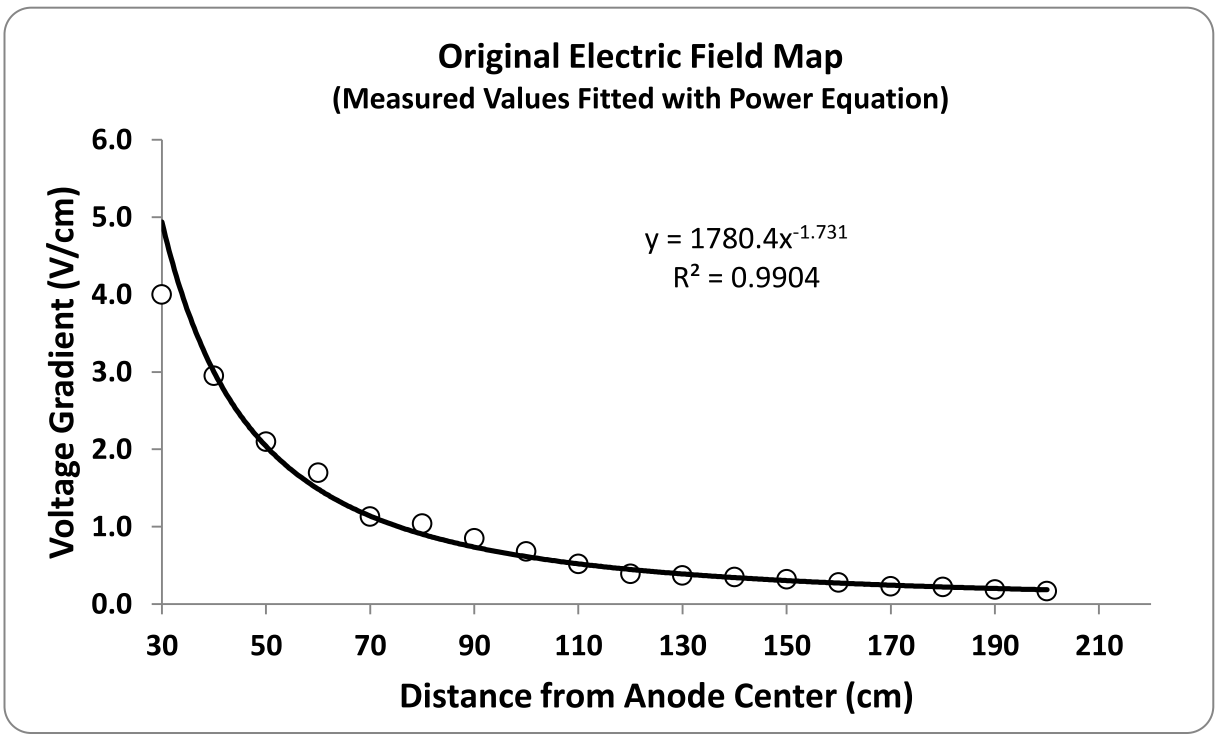

Figure 1. The electric field map for the Achilles raft at 522 V applied to the electrodes. Data was fitted with a power equation.

The Achilles was moving more than I'd prefer and movement likely resulted in measurement error. However, enough measurements were taken to overcome this deficiency and result in a good fit of the equation to the data.

Threshold settings and electric field size

"Threshold settings" mean the minimum settings (volts, amps, or power) required for "successful" electrofishing at ambient water conductivity. These threshold values can be used as a strict rule or a guide for a starting point (usually a minimum) at a sampling site.

Waveform used: Quadrapulse (a pulsed DC); within pulse packets: 240 pps & 30% duty , between pulse packets: 15 pps and 20% duty cycle.

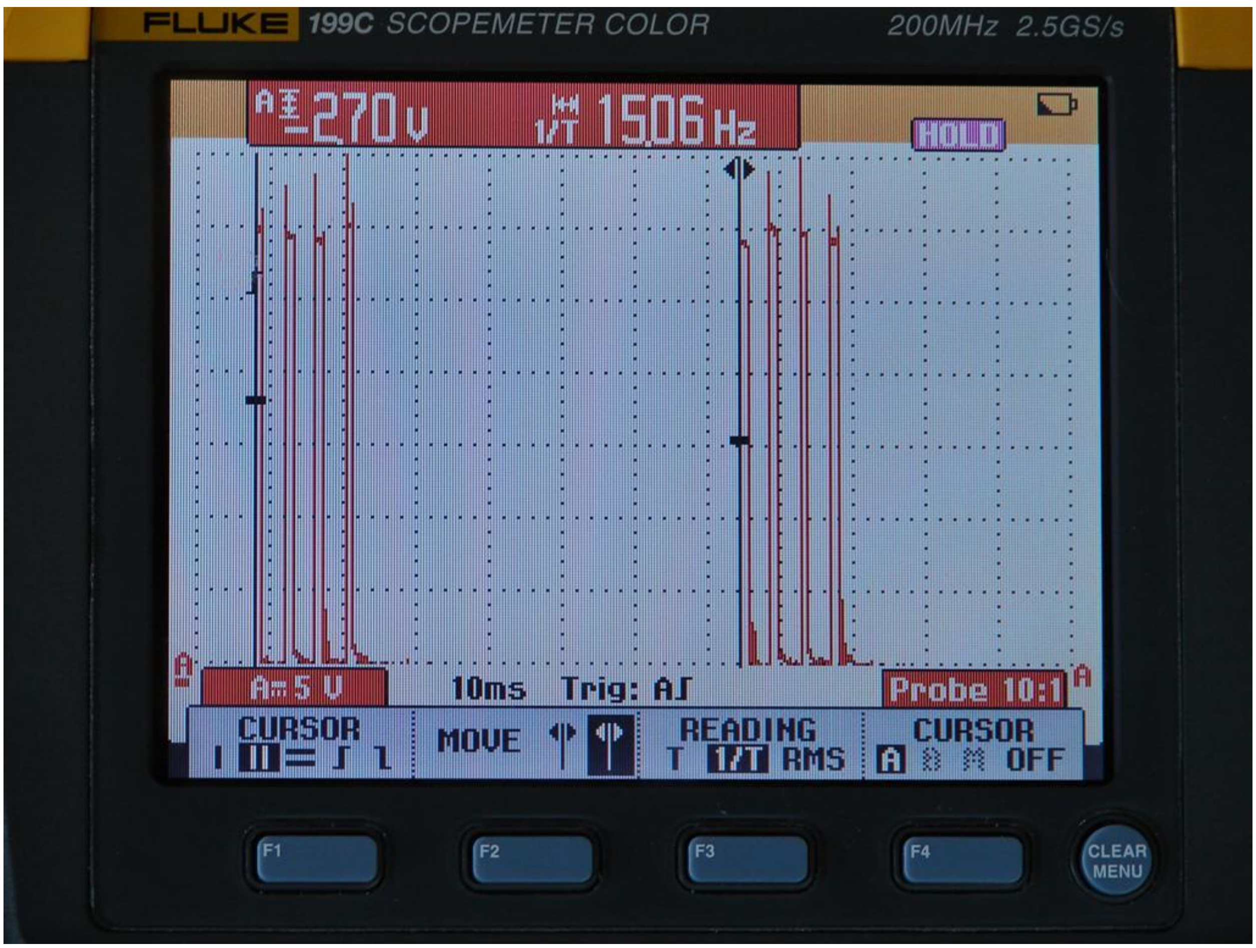

Figure 2. Scopemeter screen showing 2 pulse packets of the Quadrapulse waveform.

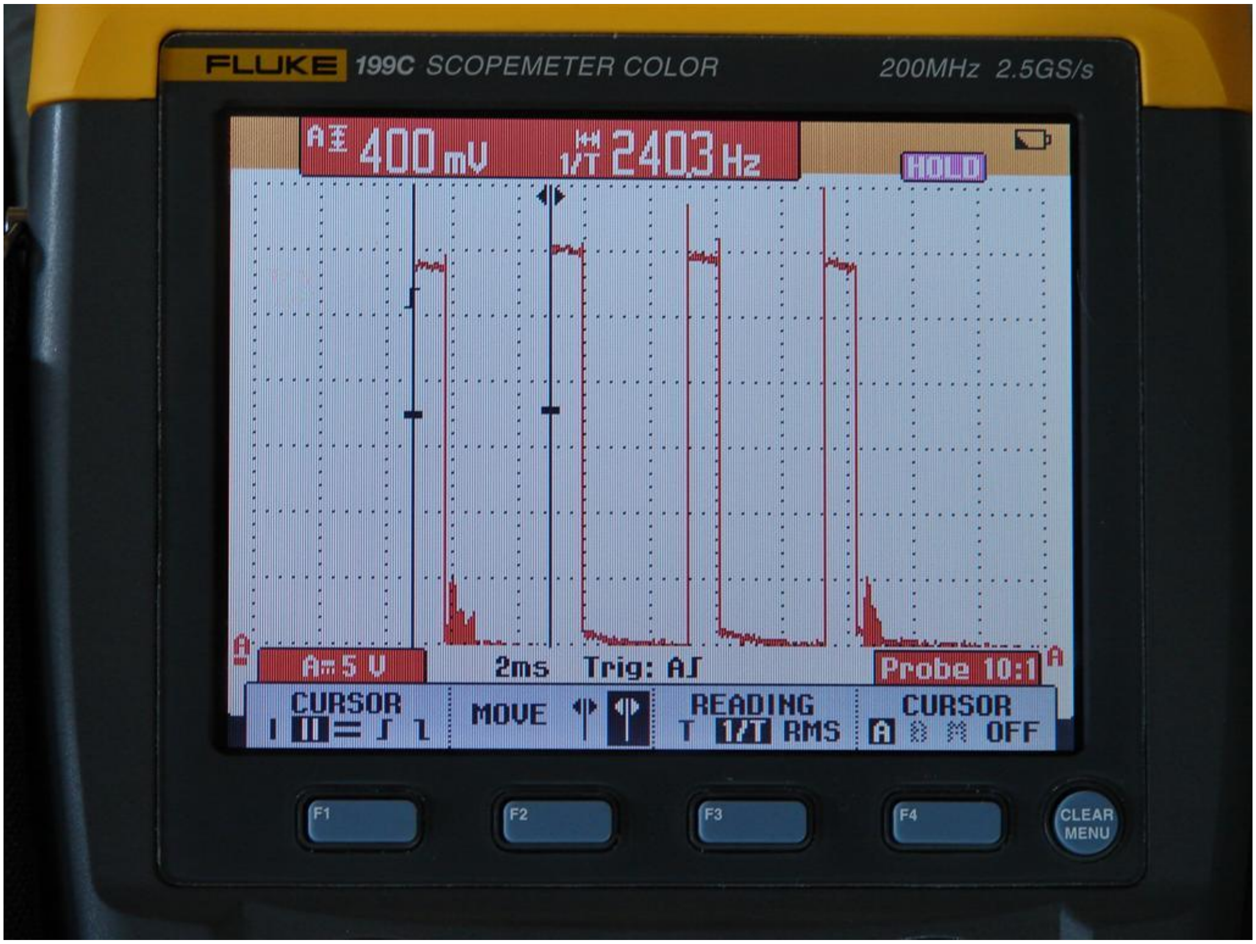

Figure 3. Scopemeter close-up of one pulse packet of Quadrapulse.

Dave Foster stated that the settings for the RTELSS project are Quadrapulse with 16 – 20 peak amps. Monitoring of the Grand Canyon fisheries by USGS/AGFD using the CPS waveform had an average amperage setting of 16 amps.

From test shocking during the day on March 31st and night sampling on April 1st, estimated settings were 560 V and 16 amps. This setting likely was near threshold. A lower amp output of 15.3 amps did not seem sufficient and rainbow trout (RBT) seemed to have good capture rates. Certainly, this setting is not overpowering the fishes at the ambient water conductivity (585 µS/cm) sampled.

Note: given electrode resistance, an adjustment to an amp threshold of 17.1 amps will be used

Lew Coggins estimated a RBT capture efficiency of 17% for the Achilles raft in the Colorado River. The efficiency level is sufficient for monitoring, particularly if variance is low. One approach to reducing variance is to standardize by volts, amps, or power.

Achilles Raft Standardization Table

Ambient Conductivity (µS/cm)	Peak Voltage (Volts)	Peak Current (Amps)	Peak Power (Watts)
550	566	16.2	9192
570	562	16.7	9411
590	559	17.2	9631
610	556	17.7	9851
630	553	18.2	10072
650	551	18.7	10293
670	548	19.2	10515
690	546	19.7	10737
710	544	20.2	10960
730	542	20.6	11182
750	540	21.1	11406
770	538	21.6	11629
790	536	22.1	11853
810	534	22.6	12077
830	533	23.1	12301
850	531	23.6	12525
870	530	24.1	12750
890	528	24.6	12974
910	527	25.0	13199
930	526	25.5	13424
950	525	26.0	13650
970	523	26.5	13875
990	522	27.0	14100
1100	517	29.7	15343

During training courses when sampling warmwater fishes, we have noticed a relatively consistent boat electric field extent when electrofishing is considered “successful”. Miranda’s immobilization threshold for mid-sized warmwater sportfish often occurs 85 – 90 cm laterally from the center of the anode. For the Achilles raft at 560 V, Miranda’s threshold (0.43 V/cm) occurred about 127 cm distant from center. This suggests that the field needed for successful electrofishing is more intense than typical electrofishing with pulsed direct current. This finding agrees with other studies where more power is needed with gated bursts (as Quadrapulse) vs. standard pulsed DC.

The amp goals in the higher part of the conductivity range are likely higher than that used for sampling the Grand Canyon. Yet, according to the power transfer concept, those levels are required for standardized power output and constant effective electric field size across water conductivity.

Equipment Capacity (Generator and Control Box)

Once a goal table is constructed, an important question is whether the power system can supply the required output for successful electrofishing. The Excel file “Boat Power Achilles” was used for the analysis.

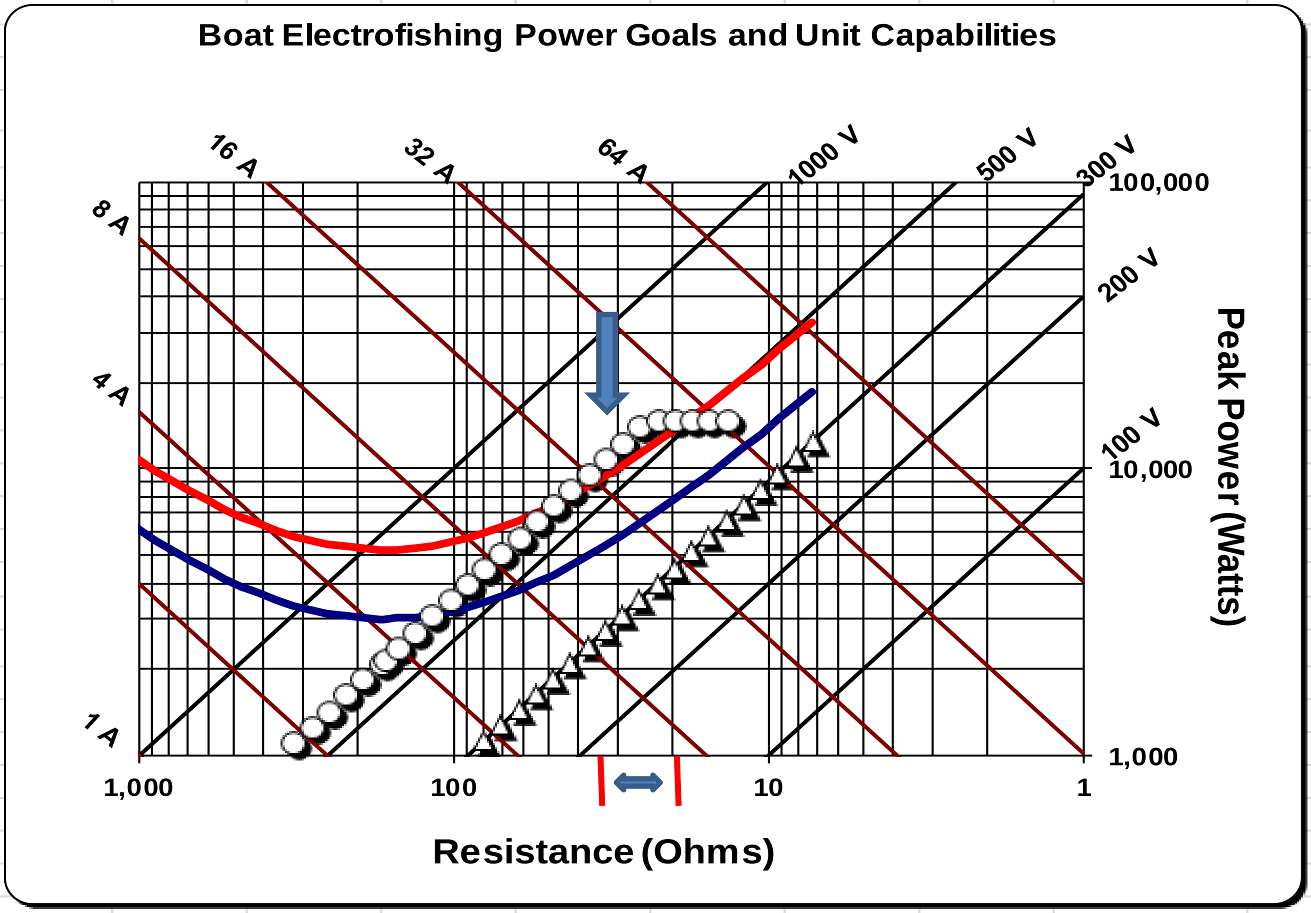

Figure 4. Output of the ETS MBS control box. Circles denote high voltage (600 V, 36 amp) range. Triangles represent low voltage (300 V, 72 amp) range. The curved blue line is Miranda’s required output for successful (and standardized) electrofishing across water conductivity. The red line is the required output for successful electrofishing for the Achilles raft in the Grand Canyon. The red lines and blue arrow on the x-axis indicate the range of water conductivity sampled in the Grand Canyon. The larger blue arrow indicates a water conductivity of 585 µS/cm.

- These results show that the high voltage setting should be used across the GC conductivity range. A test of the maximum output of the low voltage range indicated a top output of 285 V and 8.8 amps (agreeing with expected).

- For the high voltage setting, the maximum output of the gear is just above that required for successful electrofishing within the GC water conductivity range. (The maximum water conductivity that can be successfully electrofished by the Achilles raft sphere set-up is approximately 1,000 µS/cm). Unfortunately, there is little capacity to increase power (voltage or amps) if it were later determined that thresholds for successful electrofishing are actually higher than those used in this study. A test of maximum output (the gear shutdown level) resulted in a maximum of 550 V and 19 amps, corresponding with expected.
- The take-home message is that, given the thresholds determined to result in successful electrofishing and the expected water conductivity range, the Achilles raft can supply the volts, amps, and power required.

Osprey Boat

The electrode arrangement was one anode 12” sphere on the bow and the metal hull as the cathode. The control box was an *MBS-1DPQ-CR-AZ* powered by a 6,500 W generator.

Electrode Resistance

Novotny theoretical resistance at 100 µS/cm for 12" sphere = 52 Ohms

Osprey with anode sphere fully submerged:

260V, 17 I = 15.3 Ohms or 90 Ohms at 100 µS/cm

Osprey with anode sphere partially submerged (~2" exposed):

270V, 16 I = 16.8 Ohms or 99 Ohms at 100 µS/cm

If hull is 15 Ω at 100 µS/cm or 2.56 Ω at 585 µS/cm, then
the anode sphere is 84 Ω (99 - 15) at 100 µS/cm

84 Ω is quite a bit less than 104 Ω for the 11" sphere

Electric Field Mapping

The Osprey boat was moored near-shore with the bow facing the shore. The anode sphere was positioned in about 2.5’ of water with the axis of the boat perpendicular to shore. Measurements were taken at locations distant from the sphere center in a lateral vector (perpendicular to the anode boom).

Applied voltage: 295 V
Applied current: 17.5 amps

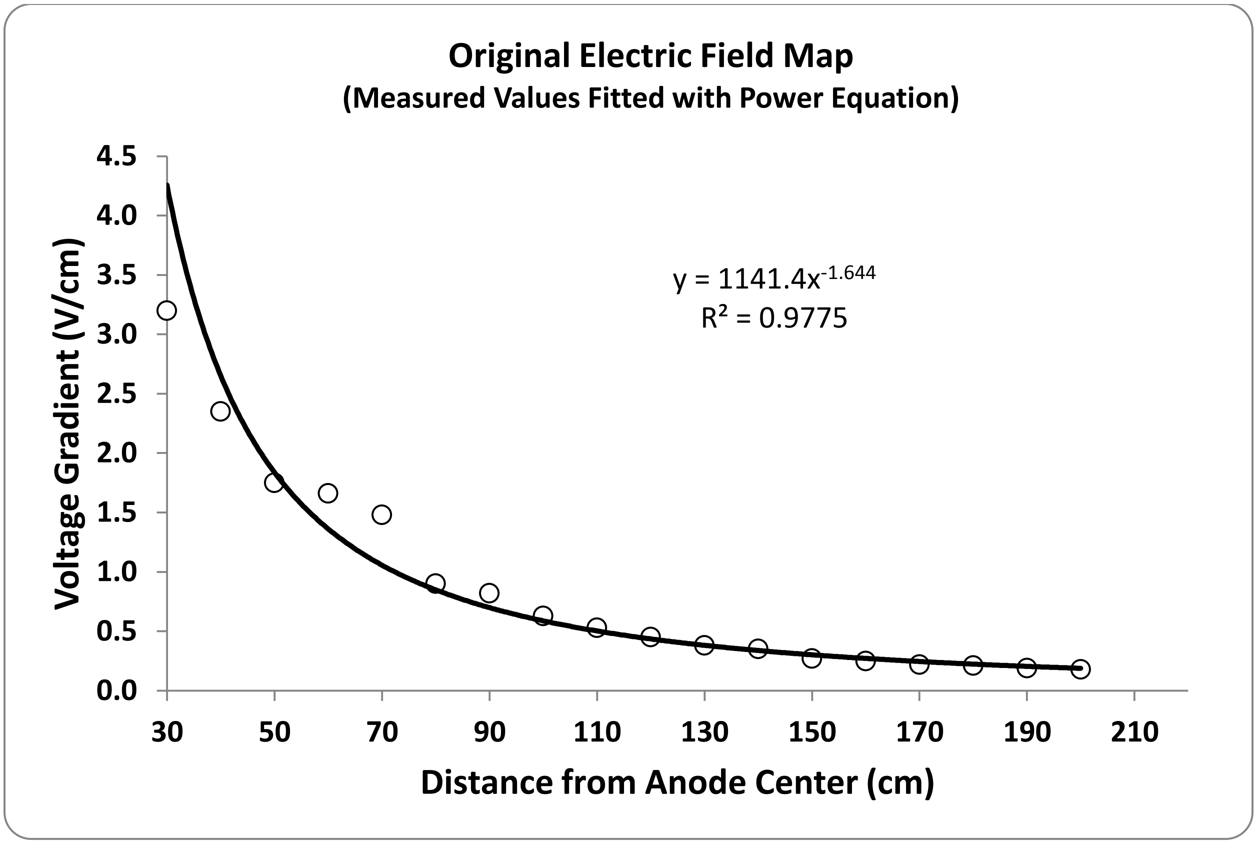

Figure 5. The electric field map for the Osprey boat at 295 V applied to the electrodes. Data was fitted with a power equation.

The Osprey also was moving more than I'd prefer and movement likely resulted in measurement error. However, enough measurements were taken to overcome this deficiency and result in a reasonable fit of the equation to the data.

Threshold settings and electric field size

"Threshold settings" mean the minimum settings (volts, amps, or power) required for "successful" electrofishing at ambient water conductivity. These threshold values can be used as a strict rule or a guide for a starting point (usually a minimum) at a sampling site.

Waveform used: Quadrapulse (a pulsed DC); within pulse packets: 240 pps & 30% duty , between pulse packets: 15 pps and 20% duty cycle.

From test shocking during the day on March 31st, estimated settings were 270 V and 16 amps. However, these possibly are not reliable values. That said, the electric field extent generated by this setting was similar to that of the Achilles (Miranda's threshold of 0.43 V/cm occurred at a distance of 114 cm from anode center).

Instead of using independently-derived threshold data for the Osprey, a goal table was derived for the Osprey that would generate electric fields identical in extent to the Achilles raft across water conductivity.

Osprey Boat Standardization Table (to correspond with the Achilles raft)

Ambient Conductivity (µS/cm)	Peak Voltage (Volts)	Peak Current (Amps)	Peak Power (Watts)
550	325	18.1	5874
570	323	18.6	6014
590	322	19.1	6154
610	320	19.7	6295
630	318	20.2	6436
650	317	20.8	6577
670	315	21.3	6719
690	314	21.9	6861
710	313	22.4	7003
730	311	22.9	7145
750	310	23.5	7288
770	309	24.0	7431
790	308	24.6	7574
810	307	25.1	7717
830	306	25.7	7860
850	306	26.2	8003
870	305	26.7	8147
890	304	27.3	8291
910	303	27.8	8434
930	302	28.4	8578
950	302	28.9	8722
970	301	29.5	8866
990	300	30.0	9010
1100	297	33.0	9804

The amp goals in the higher part of the conductivity range are likely higher than that used for sampling the Grand Canyon. Yet, according to the power transfer concept, those levels are required for standardized power output and constant effective electric field size across water conductivity.

Equipment Capacity (Generator and Control Box)

Once a goal table is constructed, an important question is whether the power system can supply the required output for successful electrofishing. The Excel file "Boat Power Osprey" was used for the analysis.

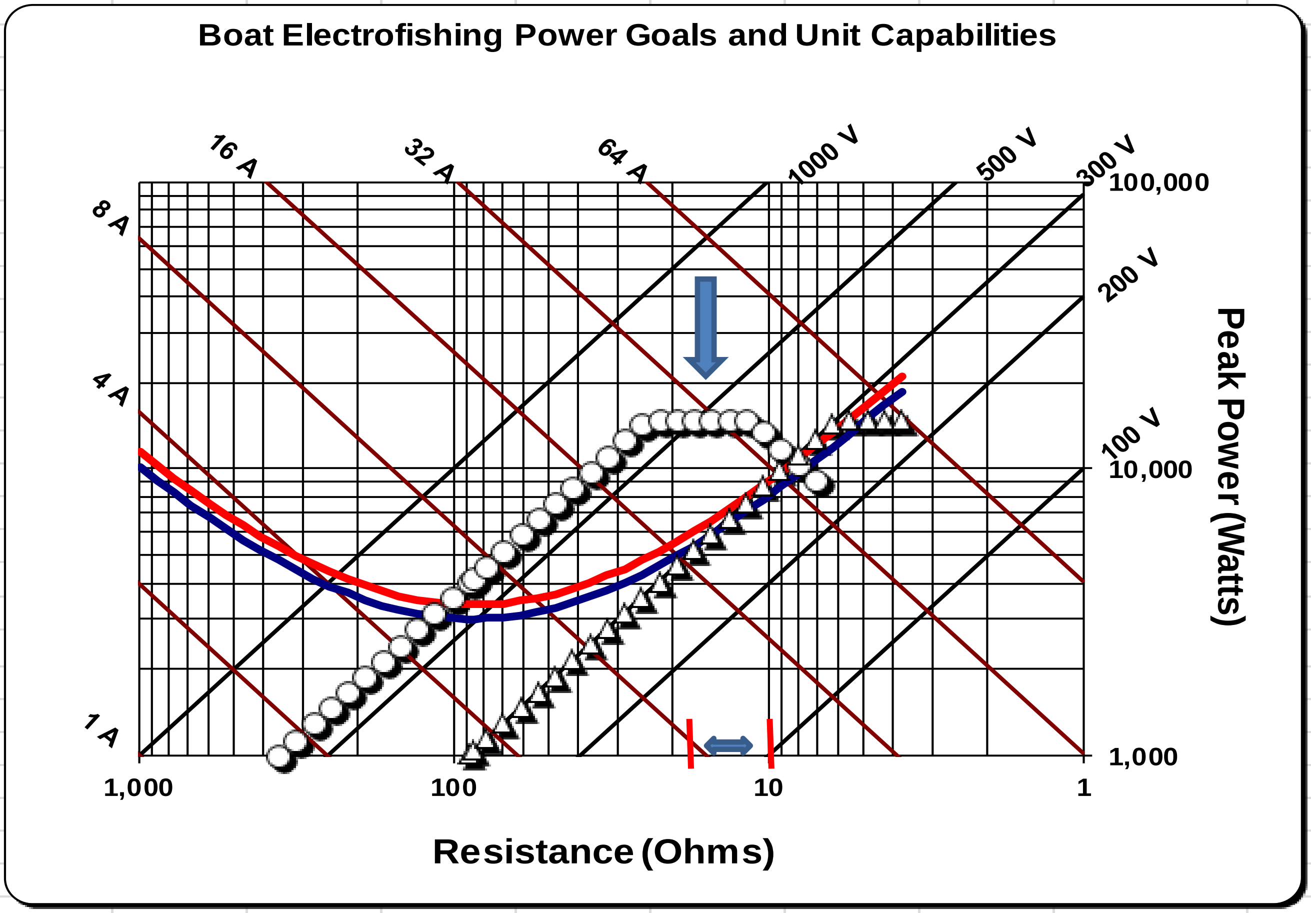

Figure 6. Output of the ETS MBS control box. Circles denote high voltage (600 V, 36 amp) range. Triangles represent low voltage (300 V, 72 amp) range. The curved blue line is Miranda's required output for successful (and standardized) electrofishing across water conductivity. The red line is the required output for successful electrofishing of the Osprey boat standardized with the Achilles in the Grand Canyon. The red lines and blue arrow on the x-axis indicate the range of water conductivity sampled in the Grand Canyon. The larger blue arrow indicates a water conductivity of 585 µS/cm.

- These results show that the high voltage setting should be used across the GC conductivity range. In case the ETS MBS control box shuts down due to amperage limitations (possibly

around 950 – 1000 µS/cm), the operator could switch to the low voltage range and still generate power required for standardization.
- For the high voltage setting, the maximum output of the gear is well above that required for successful and standardized electrofishing within the GC water conductivity range. Thus, there is significant capacity to increase power (voltage or amps) if it were later determined that thresholds for successful electrofishing are actually higher than those used in this study.
- The take-home message is that, given the thresholds determined to result in successful electrofishing, standardization with the Achilles raft, and the expected water conductivity range, the Osprey boat can supply the volts, amps, and power required.

NOTE: The above analyses regard the Quadrapulse waveform. The power requirements and capacity for successful electrofishing with the Achilles or Osprey likely would be different with a standard pulsed DC waveform, probably lower. The analyses would have to be repeated for the new waveform.

Request for Additional Information

The resistance estimates for the Osprey anode and cathode need refinement. When possible, please take the 11" sphere from the Achilles and attach as the Osprey anode. Launch the Osprey and take two sets of measurements:

1. With the anode totally submerged
2. With the anode partially submerged (in typical deployment)

First take ambient water conductivity (or specific water conductivity and water temperature). While the Osprey is in the water (near-shore), for each anode deployment, record volts and amps. Resistance can be calculated as Volts ÷ Amps. Please report the two sets of measurements with the corresponding water conductivity.