Electrofishing Standardization Protocol

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The goal of "standardization" is to decrease sampling variability (error). Reducing sampling error is assumed to make catchability or capture efficiency (q) more consistent. This may be a workable assumption, *provided there are no other unaccounted-for significant influences on catchability*, such as habitat characteristics or population size. (For example, as abundance increases, gear saturation may result and cause catchability to decrease). Management implication: less variable catchability facilitates meaningful comparisons of catch-per-unit-effort indices across water bodies and over time.

The following protocols cover standardization of single gears and fleets of gears. There are aspects common to both that will be discussed initially. Of note, standardization by power and power density can by based upon qualitative determinations of "successful" electrofishing or by quantitative determinations through concurrent estimation of catchability by mark-recapture and removal sampling, or by follow-up census (see *Appendix*). Power and power density standardization assume that water conductivity is the primary and only important efficiency factor or at least that if water conductivity is constant or changes across space/time, the effects of other potential efficiency factors remain constant.

Factors affecting catchability

There are three categories of efficiency factors:

Biological (e.g., organism size, anatomy, behavior, population density)
Environmental (e.g., characteristics of the chemical and physical environment), and
Technical (e.g., working environment, gear selected, wave form used, power capacity, statistical sampling design, crew size and experience).

Crews should identify factors that may affect catchability. These factors may be identified by observation, literature review, or found as contributing variables in efficiency prediction equations.

Biological: Efficiency differs with fish size. Determinations of successful electrofishing and power settings should be based on a minimum designated fish size and larger (target size classes ≥ a given length). Other anatomical features, as body shape and scale size, may have appreciable effect on catchability, but the importance of anatomy other than length is unsubstantiated. Behavior can lead to high or low capture probability. Sampling times may need to be restricted to specific time periods (e.g., night) and season to take advantage of fish movement. Changes in population size or density, particularly high densities, can cause non-constant catchability due to gear saturation.

Environmental: One approach to remove or lessen the influence of environmental factors consists of a sampling design that includes "go/no-go" criteria for sampling based on variable values. For instance, sampling only occurs when turbidity is within a range of NTUs, flow is within a range of exceedence discharges, or temperature is above a minimum value. Sample sites should also be within a range of stream size (e.g., average wetted width) or lake shoreline type.

Technical: Use a probabilistic statistical sampling design that designates size, location, and number of sample units. Non-probabilistic (non-random) sampling can cause catchability to vary with abundance. Crew size and experience can affect efficiency. Thus, keep crew size similar and, if the crew is novice or new to a water body, consider trial runs to work out procedures. Electrode configuration should provide a desirable field size, not overload your power source, and be similar within the fleet (for fleet standardization). Waveform attributes should be consistent (type [AC, DC, pulsed DC], shape [e.g., square vs. rounded], pulsed DC frequency, duty cycle). A power analysis of your control box/power source system should be performed to determine if your equipment can deliver required power across the water conductivity range of interest.

Power analysis of gear

The electrical output capabilities of your gear should be determined across a range of expected water conductivities. A power analysis complete with a power goal (power standardization) curve will provide the operator with an estimate of effective electrofishing range across water conductivities.

The first step is determining electrode resistance (see *Electrode Resistance Procedures*). Electrode resistance is required for a power analysis and also can inform electrode design, which is particularly important when standardizing fleets. Determining output capacity of your gear and electrode system is relatively simple. Use the *Boat Power* Excel file and *Boat Power documentation* (or use *Backpack Power* for backpack electrofishers). See the document, *Equipment Power Analysis Case Study #1,* for an example.

Standardizing a single unit

<u>Electrode design</u>: retain electrode design or evaluate percent power to the anode and electric field extent (see documents *Determining Electrode Resistance* and *Making Electric Field Measurements*). If field extent to a fish reaction threshold value (as for taxis, assuming the voltage gradient threshold is known) is considered too small, then experiment with different electrode designs.

Electrical waveform
and thresholds: Waveform selection can be based upon experience, the literature, or by experimentation. Threshold values for fish reactions (as immobilization) obtained from the literature or experimentation can be used for selecting the most efficient waveform and determining effective extent of electric field. For experimental procedures, see *Kolz, A.L. and J.B. Reynolds. 1989. Determination of Power Threshold Response Curves. Fish and Wildlife Technical Report 22, Washington, D.C*. The Excel file, *Electric Waveform Fish Conductivity Analysis Methods* may be used for analysis of experimental data.

Standardizing by power: This method requires the operator to determine threshold (minimum) control box settings required for successful electrofishing. Settings can be power, voltage, and/or amperage. An assumption of this approach is that water conductivity is the primary factor affecting catchability or that the other efficiency factors are constant in their influence.

1) Select target species and size classes.
2) Go to an area similar in physical characteristics to your sample sites or go one of your sampling sites.
3) Take ambient water conductivity.
4) Decide on a waveform type (AC, DC, PDC), if PDC, select frequency and duty cycle.
5) Start at a low (or a high) voltage setting and start electrofishing.
6) Note if fish reactions are conducive to successful electrofishing. Another approach to determine successful electrofishing is the concurrent estimation of catchability via mark-recapture or removal (depletion) sampling (see *Appendix*).
7) If electrofishing deemed successful, then reduce voltage and make another run. Repeat until applied voltage and power are too low to result in successful electrofishing.
8) If unsuccessful, increase applied voltage and repeat observations.
9) Upon finding the threshold settings for successful electrofishing, record all outputs provided by metering (voltage, amperage, power).
10) Use *EF_Goal* or *Electrofishing with Power* Excel files to derive tables and curves of applied power, voltage, or current goals for the water body types/size that you will sample.

Application: Subsequently, at a sample site, take ambient water conductivity. Consult your applied output goal table and adjust power, voltage, or amperage to the threshold value required for successful electrofishing at the measured conductivity.

Note: If there are other efficiency factors operating besides water conductivity, the power goal curves may be conservative and the shape of the power goal curve may be unknown. Probably the best alternative is to determine threshold settings near the sample sites, prior to sampling. In other words, perform a trial run near the sample site, repeating the above protocol until threshold settings are determined. These settings are then used in the sample site. This process would need to be repeated at each sampling site if the sampling sites differ from each other in important efficiency factors (as conductivity, turbidity, size, woody debris, etc.).

Procedures and data forms are found in *Field forms for Standardization* and *Field forms for Standardization short form*.

Finally, if your electric field pattern has been mapped, you can determine the size of the electric field generated by the threshold setting that lead to "successful" electrofishing or acceptable capture efficiency. This electric field size would be the size required for successful electrofishing. This information can be helpful particularly when standardizing fleets of gear. That is, all units should generate the same field configuration at a given water conductivity.

<u>Standardizing by power density</u>: This method requires that electric field threshold values (e.g., voltage gradients) required for successful electrofishing of your target species are known. In addition, the operator must have mapped the electric field. By deciding upon the distance that the threshold voltage gradient or power density should be away from the electrodes, you can use *Electrofishing with Power* (Voltage Goals, Field Size tab) and the documentation *An Introduction to Electrofishing with Power*. The result will be a voltage goal table by water conductivity. By adjusting applied voltage according to conductivity, the effective field size will remain constant. This and the power standardization method should give very similar results. An assumption of this approach as well is that water conductivity is the primary factor affecting catchability or that the other efficiency factors are constant in their influence.

1) Select target species and size classes.
2) Map the electric field of your unit. For methods, see *Making Electric Field Measurements*.

Option #1

1) From the literature or experimentation, determine threshold voltage gradients or power densities for capture prone responses, as taxis or immobilization. (Be aware that these thresholds are based on a particular waveform type (AC, DC, PDC), shape, and, if PDC, frequency and duty cycle).
2) Select a capture-prone response of interest and the corresponding electric field thresholds. In other words, choose the response(s) needed, as taxis or immobilization,

with the corresponding minimum voltage gradient and power density required causing the response.

3) Decide on the size of the effective electric field; in other words, select the distance from the boom (or hand-held boom if using a backpack electrofisher) to the threshold voltage gradient or power density.
4) Input your field map (taken at a particular applied voltage), threshold voltage gradient (with the corresponding water conductivity), and desired extent of electric field into *Electrofishing with Power* (Voltage Goals, Field Size tab)

   The product will be an applied voltage goal map by water conductivity that the operator will use to standardize by power density.

Option #2

1) Go to an area similar in physical characteristics to your sample sites or go one of your sampling sites.
2) Follow the procedure for Standardizing by Power up to and including Step #9.
3) Although any voltage gradient would do, we recommend that you determine the field location of the threshold voltage gradient causing the desired fish response, if known; whatever voltage gradient is selected, the distance from the electrode is the desired field size.
4) Input your field map (taken at a particular applied voltage), threshold voltage gradient (with the corresponding water conductivity), and desired extent of electric field into *Electrofishing with Power* (Voltage Goals, Field Size tab)

   The product will be an applied voltage goal map by water conductivity that the operator will use to standardize by power density.

Standardizing multiple gears (fleets)

Electrode design: Electrode design should be similar across gear. The objective is the projection of a field that is effective and similar across units. The next step is to map electric fields of all units and evaluate percent power to the anode (see documents *Determining Electrode Resistance* and *Making Electric Field Measurements*). If field size at a fish reaction threshold value, assuming this is known, is considered too small, then experiment with different electrode designs.

Electrical waveform and thresholds: Waveform selection can be based upon experience, the literature, or by experimentation. Threshold values for fish reactions (as immobilization) obtained from the literature or experimentation can be used for selecting the most efficient waveform and determining effective extent of electric field. For experimental procedures, see *Kolz, A.L. and J.B. Reynolds. 1989. Determination of Power Threshold Response Curves. Fish and Wildlife Technical Report 22, Washington, D.C*. The Excel file, *Electric Waveform Fish Conductivity Analysis Methods* may be used for analysis of experimental data.

Standardizing by power: This method requires operators to determine threshold (minimum) control box settings required for successful electrofishing. If the boats are very similar in electrode design and electrical output, then this approach could suffice for standardizing a fleet. One goal table (power, voltage, or current) would be used for all equipment. A good example of this approach is *Burkhardt, R.W. and S. Gutreuter. 1995. Improving electrofishing catch consistency by standardizing power. North American Journal of Fisheries Management 15:375 – 381*. If the electrode designs differ among boats or units, this approach still can be used. Each boat would have its unique goal table. As always, an assumption of this approach is that water conductivity is the primary factor affecting catchability or that the other efficiency factors are constant in their influence.

See power standardization methods under ***Standardizing a Single Unit***. If electrofishers have very similar electrode designs and applied waveform attributes, then all boats could run a trial at the same water conductivity and an average threshold setting used for deriving the goal table.

Standardizing by power density: This method requires that 1) electric field threshold values (e.g., voltage gradients) required for successful electrofishing of your target species or 2) the electric field configuration associated with "successful" electrofishing are known. If the latter, then any voltage gradient can be selected for input into the analysis. Regardless, the operator must have mapped the electric field. By deciding upon the distance that the threshold voltage gradient or power density should be away from the electrodes, you can use *Electrofishing with Power* (Voltage Goals, Field Size tab) and the documentation *An Introduction to Electrofishing with Power*. The result will be a voltage goal table by water conductivity. By adjusting applied voltage according to conductivity, the effective field size will remain constant. Each boat can have a different voltage goal table. The important aspect is that the effective field sizes are the same across different electrofishers and water conductivities. An assumption of this approach is that water conductivity is the primary factor affecting catchability or that the other efficiency factors are constant in their influence.

1) Select target species and size classes.
2) Map the electric field of your unit. For methods, see *Making Electric Field Measurements*.

Option #1

1) If available from the literature or experimentation, determine threshold voltage gradients or power densities for capture prone responses, as taxis or immobilization. (Be aware that these thresholds are based on a particular waveform type (AC, DC, PDC), shape, and, if PDC, frequency and duty cycle).
2) Select a capture-prone response of interest and the corresponding electric field thresholds; if threshold field values are unknown, select an arbitrary voltage gradient from an electric field that resulted in successful electrofishing.
3) Decide on the size of the effective electric field; in other words, select the distance from the boom (or hand-held boom if using a backpack electrofisher) to the threshold (or arbitrary) voltage gradient or power density.
4) Input each boat or unit's field map (taken at a particular applied voltage), threshold (arbitrary) voltage gradient with the corresponding water conductivity, and desired extent of electric field into *Electrofishing with Power* (Voltage Goals, Field Size tab)

   The product will be an applied voltage goal map by water conductivity that the operator will use to standardize by power density. Each boat or unit may have a different voltage goal table if their electrodes are dissimilar or if waveforms vary somewhat (as rounded vs. square-shaped pulses) as a result of using different control box models.

Option #2

5) Go to an area similar in physical characteristics to your sample sites or go one of your sampling sites.
6) Follow the procedure for <u>Standardizing by Power</u> up to and including Step #9.
7) Although any voltage gradient would do, we recommend that you determine the location of the threshold voltage gradient in the electric field, <u>if known</u>; whatever voltage gradient is selected, the distance from the electrode is the desired field size.
8) Input your field map (taken at a particular applied voltage), threshold (arbitrary) voltage gradient with the corresponding water conductivity, and desired extent of electric field into *Electrofishing with Power* (Voltage Goals, Field Size tab)

   The product will be an applied voltage goal map by water conductivity that the operator will use to standardize by power density. Each boat or unit may have a different voltage goal table if their electrodes are dissimilar or if waveforms vary somewhat (as rounded vs. square-shaped pulses) as a result of using different control box models.

Appendix

Determination of "Successful" Electrofishing

This concept seems easy but there are pitfalls to consider. If subjectively determined, "successful" must be defined. Does successful mean that the taxis response is common, that few fish are observed that escape, that fishes are immobilized to the sides as well as in front of the booms? You should decide upon a capture-prone response of interest and a rough proportion of escapes (a lot, few, very few). Make sure that the power source and control box can deliver sufficient power to cause the extent of the desired capture-prone response (see the *Boat Power* Excel file and *Boat Power documentation*). That is, don't let an under-powered unit cause you to change your definition of "success".

Another approach, instead of subjectively determined success, is to base success on capture efficiency (the proportion of fish captured in one unit of effort, *q*). The first step 1) is to determine the required capture probability needed for the questions management is trying to answer. The required capture probability can be that associated with subjectively determined "successful" electrofishing or by modeling the observation process. Two examples of modeling, the likelihood of detecting a species and trend analysis of population size, can be explored using *Detection Probability* (Excel), *Documentation for Detection Probability*, and *Trend Analysis* (Excel).

Next, 2) subjectively determine "successful" electrofishing as you would when following the standardizing by power protocol.

Finally, 3) move to a nearby sample site, use those settings to estimate capture probability via Mark-Recapture (use *Mt Model* [Excel], and *Mt Model Documentation*), depletion (use *Depletion Sampling- 3 Pass* [Excel], *Depletion Sampling- 4 Pass* [Excel], *Depletion Sampling Documentation*), or total census (piscicide) sampling. The estimated capture efficiency defines "successful" electrofishing. Use the capture efficiency estimate in the Excel files for species detection and trend analysis. See if the statistical power to detect a species or estimate trends in abundance is acceptable. If so, you are done. You have the settings and electric field needed to standardize by power or power density. If the capture efficiency is not high enough to provide adequate statistical power, then you must consider alternatives to electrode design, power source, applying electrical power levels above threshold*, or mixing in another category of gear to increase capture efficiency.

*A research approach involves correlating different applied power (voltage or current) levels and/or associated threshold voltage gradients with capture efficiencies. Does capture efficiency increase significantly above applied power threshold settings? Where does capture efficiency gains with increased applied power levels asymptote? If you have modeled the observation process, can you reach the required capture efficiency?

When Water Conductivity is not the Only Important Efficiency Factor

Standardizing by power or power density may not be enough if water conductivity is not the only important efficiency factor or if the influences of other factors change across time or space. If this situation occurs, then the shape of the power, voltage, or current goal curves may be different from that determined by the power transfer model. (The power goal curves are still valuable, however, because they at least provide a baseline of power needed). One alternative protocol is to perform a trial run to determine threshold control box settings near the sampling site(s) each time they are sampled. The operator will not follow a power (or voltage or current) goal table but instead use the threshold settings determined that day prior to actual sampling.

Using Capture Efficiencies to Adjust Catch in Sampling Units (Catch-Per-Unit-Effort) to Abundance

For higher resolution sampling, and if you cannot stabilize catchability by standardization practices, catch in each sampling unit should be adjusted by capture efficiency (i.e., catchability) to derive population abundance estimates. The need for this approach can be determined by estimating the extent of capture efficiency variation under standardization or via modeling the observation process (e.g., evaluating the likelihood of detecting a species or trends in population size using such tools as *Detection Probability* (Excel), *Documentation for Detection Probability*, and *Trend Analysis* [Excel]).

The equation is

$$N = \frac{CPUE}{q}$$

where,

N = estimated population abundance within a sample unit
CPUE = catch per unit effort, with effort equaling one sample unit
q = capture efficiency (proportion of population captured within a sampling unit)*

At a sampling site, capture efficiency must be determined. Approaches include the use of capture efficiency or “calibration” equations (see *Capture Efficiency Models* [Excel]) and capture efficiency estimation concurrent with sampling (e.g., via mark-recapture or depletion).

Finally, divide your count data (CPUE) obtained at the site by capture efficiency. The result is an estimate of population abundance as illustrated above.

*In reality, sample unit catch is divided by capture probability (p). The relationship with q is: p = q x effort. Since effort is “one” (covers entire sampling unit), then capture probability and efficiency are the same.