DRAFT

EIFAC WORKING PARTY ON FISH MONITORING IN FRESH WATERS

INFORMATION NOTE

Electric Fishing Best Practice

Choice of Equipment and Outputs to Achieve Efficient and Safe Fish Capture

1. Introduction

The purpose of this information note is to provide specific guidance on choice of electric fishing equipment and correct adjustment of electrical output settings to achieve the optimum combinations of efficient fish capture and fish welfare under the range of environmental conditions.

1.1 Contents

- voltages
- output type and waveform
- anode dimensions,
- cathode size and shape
- frequency, power output (duty-cycle settings)

Variables considered include:

- conductivity
- temperature
- target species / sizes
- presence of sensitive/rare/valuable fish

2. Voltage

2.1 The voltage required to be applied at the electrodes in order to attract and stun fish will vary according to

- ambient water conductivity
- the output type used (smooth Direct Current or Pulsed Direct Current)
- size of effective capture field required.

2.2 Conductivity.
Low conductivity waters will generally require higher applied voltages for fish capture than high conductivity waters. This is because when the water being fished is **low conductivity** (<150 microsiemens/centimetre - µs/cm), a correspondingly higher voltage gradient is required to elicit a given response from a fish at a given point in the electric field than is the case at high conductivity.

At higher temperatures the increasing disparity between fish conductivity and water conductivity in such waters may render electric fishing more dangerous to the fish and it should therefore be avoided.

Use of higher voltage systems which utilise transformers to generate up to 600 V, has been practised in some low conductivity waters, however users should be aware that very high and potentially dangerous voltage gradients will occur close to the anode. Recent field trials in such waters comparing these high voltage systems with standard equipment operating at 300 Volts DC failed to demonstrate any clear advantage in terms of fish capture.

The recommended applied voltages to be selected for fishing in low conductivity waters should therefore be 300 - 400 Volts.

2.3 Medium and High conductivities.
At medium and high conductivities, progressively lower voltages will be effective in fish capture because a lower voltage gradient is needed to elicit a response from fish at a given point in the electric field in higher conductivity waters.

The following are therefore recommended as a guide:

- at conductivities of 150 - 500 µs/cm, select 200-300 Volts
- 500-800 µs/cm, select 150-200 volts
- 800-1000 µs/cm, 120-180 Volts
- >1000µs/cm : 100-150 Volts

The overall aim during any electric fishing operation should be to maximise the effective field of fish capture whilst minimising the extent of the zone of very high voltage gradient around the anodes in which fish can be damaged. Where very sensitive or valuable species are present, operators should consider further reducing the risk of damage to fish by reducing applied voltage even if this means some compromise of fishing efficiency.

The right-hand diagrams in the "Electrocalc" spreadsheet give an indication the effective size (horizontal axis) of electric fields, based on nominal voltage gradients required to catch fish, when using different anode sizes at different applied voltages, under scenarios of low and high conductivity.

As a general approach, electric fishing under any field conditions should be started at the lower end of the range of voltages recommended for those conditions.

2.4 Waveform
As a rough guide, in medium conductivity waters, *attraction* of fish toward the anode can be achieved at voltage gradients of 0.1 volt/cm using Direct Current and 0.3 volt/cm when using Pulsed Direct Current.

Immobilisation of fish using DC can be achieved at voltage gradients of 1.0 volt/cm whilst with PDC this can occur at gradients as low as 0.6 volt/cm. Every attempt should be made to prevent the fish coming closer to the anode than the distance at which voltage gradient is sufficient for immobilisation and fish should never be touched with an energised anode.

In low conductivity waters, the voltage gradients needed to elicit attraction and immobilisation will be slightly higher than those given above; whereas in higher conductivity water these values will be slightly lower.

Larger fish are generally susceptible to lower voltage gradients than smaller fish in any given situation.

2.5 Effective size of capture field required.
In most electric fishing situations it is desirable to create as large an effective capture field as large as possible. However in shallow, narrow streams there is no need to create a field that will attract fish from many metres away since any fish present will never be far from the fisher. In very turbid water there is equally no point in stunning fish at a depth/distance form which they cannot be seen and retrieved.

This also depends to some extent the species and sizes of fish being targeted. Small fish species with limited mobility such as bullhead can be captured using small effective electric fields employing relatively low voltages – even in larger rivers.

Hence when fishing in very small streams the operator should consider using lower voltages than those indicated in 2.3.

Generators used as the power source for electric fishing are typically Alternating Current machines producing 230-240 Volts output. The output from the generator is modified after it has entered the control box to produce the waveform and output type chosen by the user.

2.6 Measuring the applied voltage
The control box circuitry in the more modern electric fishing systems enables voltage to be selected and controlled systematically. In earlier designs, voltage and to duty cycle cannot be varied independently, and these models are usually fitted with an *input* voltmeter_which only measures the voltage produced by the generator, not that applied at the electrodes, which is the main concern of the fisher.

3. Anode dimensions.

3.1 *The use of very small anodes (< 25cm diameter ring) is not recommended under normal circumstances as they result in a small but intense electric field.* The aim should be to use as large a diameter anode (= surface area) as is practicable. The constraints on anode size in low conductivity waters will be the physical limitations imposed by the nature of the site and ease of handling by the operator. If the physical nature of the stream necessitates the use of a very small anode (for instance fishing for bullhead or 0+ salmonids under very low water conditions in a boulder-strewn stream) then the applied voltage must be reduced accordingly, perhaps to as low as 50 Volts –since in a case such as this, size of capture field is not an issue.

In higher conductivity waters maximum usable anode size may be limited by power available. Diagrams showing the size of effective electric fields using different applied voltages and different sized anodes, using both pulsed and smooth DC, and the power requirements of these different configurations are shown in the Electrocalc spreadsheet.

3.2 It is recommended that the standard anode size for normal use is a stainless steel ring, diameter 60 cm. *Thicker gauge steel is heavier, stronger and creates a larger surface area but has relatively little effect on electrode resistance and field characteristics: 10mm gauge is a good compromise. Teams should carry other diameter rings (40 cm, 30 cm and 25 cm) to cope with situations where very high conductivity places excessive demands on power available, or where the physical nature of the stream renders a large diameter anode impractical, as outlined in 3.1 above*.

3.3 As a general rule, *no more than one anode (40-60 cm diameter) is required per 5 m width or river channel being fished.* If more than one anode of this size is used in a channel narrower than this, the size of effective electric field around each one will be reduced, and the operation will be less cost effective and wasteful of power.

In wider channels where it is desirable to increase the number of anodes, the surface area of cathodes must also be increased *pro rata* (see below) in order to gain maximum benefit from the increased anode size. Note however that power requirements will increase (see left-hand figures in Electrocalc). When fishing with multiple anodes it is not good practice to hold the anodes heads closer than about 3m apart because the size of effective electric field around each one will be reduced, with the potential for reduced capture efficiency. Notwithstanding this, users should be aware that if too great a gap is left between a pair of anodes for too long during a fishing operation, fish may pass between the two anodes and not be caught.

4. Cathode size and shape

4.1 *The system should always comprise a cathode surface area that is larger as the surface area of the anode(s).* Cathode: anode surface area ratios of as large as 30:1 have been quoted in the literature but there is a limit to the practicality of such configurations. Long narrow cathodes such as copper braids give a better surface area: resistance ratio than metal plates or mesh grids. However braids produce more intense cathode fields in the immediate proximity of the tip of the braid, which can be harmful in situations where fish may come close to the cathode. In such cases a cathode grid or grids are preferable to braid.

4.2 *It is recommended that the standard cathode should be at least a 3 –metre length of 25 mm wide copper earthing braid or a sheet of perforated steel or mesh of at least 75 cm x 75 cm square or other shape of equivalent surface area.*

If the surface area of the anodes is doubled then the cathode surface area should also be doubled, use of two or more cathodes spaced some distance apart is strongly recommended. Control boxes for use with more than one anode should if possible be fitted with extra cathode sockets. If extra cathode sockets are not fitted, then multiple cathode braids or grids can be fed from a single control box socket using a trouser joint and a spacing device made from non-conducting material. The assembly of such a trouser-joint system must be carried out only by a qualified electrician.

4.3 Very long cathodes may be impractical for backpack electric fishing where the cathode is dragged behind the fisher, nevertheless the cathode should comprise *at least 2 metres* of braid rather than the 0.75 metre cathodes commonly supplied with backpack sets.

4.4 As a general rule for anodes and cathodes, bigger is better, but there is a law of diminishing returns and little advantage will be gained by using much larger sizes than those recommended.

5. Waveform.

5.1 Smooth Direct Current (DC)
Use of smooth direct current for electric fishing potentially offers a number of advantages over other waveforms notably in respect of attraction properties and in terms of fish welfare and *DC should be used wherever and whenever it is practicable*. However its disadvantages are that it is a "power-hungry" waveform and its effectiveness is more prone to disruption by local variations in the conductivity of the river bed. It also has limited ability to actually immobilise fish. DC is particularly effective in low-conductivity waters where power demands are generally small.

5.1.1 *When using backpack gear and single anode, it is possible to fish effectively with smooth DC at conductivities < 150 μs/cm.* At higher conductivities it may be necessary to revert to generator-based systems or switch to the pulsed DC option, since maximum output from the modern backpack units is nominally 200 – 500 w.

5.1.2 *Portable generator based systems can be used to fish with smooth DC in waters of conductivity up to 500 μs/cm.* Note that generators larger than 4 - 5 kVA (depending on model) are not considered portable, and hence power output from such a machine imposes an upper limit on the use of Direct Current. The power requirements can be estimated from the Electrocalc spreadsheet.

5.1.3 *Ensure that the control box you are using is rated adequately for the currents expected.* Reading from the left-hand charts in the single-and double anode spreadsheets in Electrocalc, currents can be estimated by (0.6 x power requirement/selected voltage).

For instance fishing DC with a single anode of 400 mm diameter and 1500mm x 25mm braid cathode, in water of conductivity 300 μs/cm with a voltage set at 250V, power requirement will be 1600 watts and current drawn will be 3.8 amps.

5.2 Pulsed Direct Current (PDC).
5.2.1 When conductivities exceed the values at which efficient fishing can take place using DC, pulsed DC is the recommended option. Its attractive properties are not as good as smooth DC but are better at immobilising fish. Other waveforms eg exponential decay, burst and sweep are available on some models, however the capture efficiency and fish welfare characteristics have not yet been fully evaluated and so their use cannot be recommended for routine electric fishing at this stage.

5.2.2 *Backpack systems can be used to fish in pulsed DC mode in waters up to around 500 μs/cm and exceptionally up to 800 μs/cm when low duty-cycle is selected.*

5.2.3 Power requirements for PDC are generally much lower than for DC. However it is still necessary to ensure that sufficient power is available for the waters being fished, the applied voltage which has been selected and the electrode configuration being used to maximise the capture field. Always use the Electrocalc spreadsheet to check that there is sufficient capacity to deal with the water it is intended to fish.

6. Choice of frequency when using pulsed DC

6.1. Choice of frequency will be influenced primarily by the species being sought, bearing in mind that under normal circumstances it is desired to maximise the attractive properties of the electric field whilst reducing the immobilisation zone to a minimum. Research has shown that whilst medium to high frequencies are more effective in capturing fish of some species groups, particularly salmonids, these are also more harmful.

Paradoxically, very high frequencies, > 400 Hz , have been shown to be both effective and relatively benign for a range of species, and point abundance sampling of cyprinid fry has been successfully carried out using 400 – 600 Hz. However, many electric fishing control boxes do not include such high settings as an option.

6.1.2 Salmonids: frequencies of *40-60 Hz* are as effective in attracting fish as the commonly-used but potentially more damaging 100Hz. 40 Hz will still immobilise salmonids but only within a much closer proximity to the anode. The use of 100 Hz should be avoided. 10 Hz will attract salmonids but not stun.

6.1.3 Cyprinids: optimum frequencies may vary but for roach *30 Hz* has been shown to give both good attraction and good immobilisation. Switching to 10hz reduces the zone of immobilisation whilst increasing attraction properties, however there may be difficulties in capturing cyprinids in some circumstances if they are only immobilised in a very small zone around the anode. An added benefit of use of 10hz is that salmonids will be only slightly influenced by the electric field and unlikely to be immobilised at all. Therefore where adult salmonids are present and coarse fish surveys are being undertaken it is recommended that if pulsed DC is used, it is worth considering fishing with 10hz.

6.1.4 Perch are more similar to salmonids in their response to electric fields and 100 Hz has the best attraction and immobilisation properties, however as fish damage (to perch and other species) is more likely at this frequency, *30-40 Hz* is recommended for percids though where good immobilisation is also required then *10 Hz* is better

6.1.5 Pike – no specific references have yet been found in the literature but fishing at *30 Hz* has proved effective.

6.1.6 Eels - most frequencies investigated were effective in both attracting and immobilising eels, so bearing in mind the potentially more harmful effects of higher frequencies on some other species, frequencies of *10-40 Hz* should be employed as standard.

The attributes of other intermediate frequencies eg 5 hz, 20hz, have not been reported to any extent in the literature examined but may yet prove more favourable still than the frequencies quoted.

7. Pulse width/duty cycle.

7.1 Pulse width refers to the duration of each individual pulse of electricity and can be expressed in milliseconds or in duty cycle, which is expressed as the percentage of the electrical cycle during which electricity actually flows. The greater the duty cycle selected, the higher will be the current drawn and power required.

7.2 *When fishing with pulsed DC, duty cycle should as a rule be kept to a minimum*: when optimum attraction frequencies for the species sought are employed, increasing pulse width has little effect on attraction properties of the field, though often improves immobilisation strength. Confinement to low pulse width reduces the possibility of fish damage and conserves power.

7.3 *In more conductive water, it may be necessary to increase duty cycle if fish are not being caught despite being expected; Duty cycle should never be turned up above 50% of what is available as per the control box.*

7.4 *It is recommended that when using PDC, fishing should start with duty cycle set at 10%.* For control boxes that do not have independently variable voltage and duty cycle control, fishing should start with the "select power" dial turned down to perhaps a quarter of its range.

8. Examples

Case 1:

The site is a medium sized upland stream (3-4 m width) with low conductivity (60 µs/cm). Target species are mainly 0+ salmonids. Depth is mostly 10 – 30 cm though there is one wider, deep (1m) pool under a bridge at the bottom of the site, which may contain some larger brown trout. The site has quite good cover with small willow bushes and an undercut bank for much of its length.

Low conductivity enables the use of smooth DC at 300 V, deployed from a backpack machine with a 40 cm anode and 2 metre braid cathode. This will give an attraction field of almost 2 metres and fish will be immobilised at around 25 cm from the anode. The width and depth of the stream means a single 40-cm anode can easily be wielded to cover the channel; the presence of large cobbles protruding above the surface makes a larger anode unwieldy. The 2 metre length of 25mm copper braid is a sensible maximum for backpack work. Power requirement will be around 500 watts, which the backpacks will cope with though battery life will be relatively short. Current will be around 0.9 A.

However the wider pool under the bridge may require pulsed DC in order to immobilise the larger trout which may otherwise simply be chased around the pool. Here 300 V pulsed DC set at 40 Hz and 20% pulse width, with a larger anode head (60 cm) will be more effective. The attraction field will be smaller than with DC (1m from the anode) but immobilisation will occur at around 50 cm from the anode. Power requirement will be just over 100 W.

Case 2:

The site is the middle reaches of a northern rain fed river, around 15 metres wide, mostly shallow with cobbles, but with a deep willow-lined run down one bank with depths up to 1.5 m. and there are several clumps of *Ranunculus* alongside the willows which have accumulated rafts of debris. Target species are mixed coarse fish with some brown trout possible. Conductivity is around 350 µs/cm.

Most if not all of the fish take to cover as soon as work starts. Drawing fish out of the cover will be a prerequisite for a successful survey and so smooth DC at 240 V is deployed from a boat propelled slowly upstream by a small outboard. As large an attraction field as possible is desirable so a single 60-cm anode is used with a 3 metre cathode. This gives an attraction field of around 2metres but immobilisation will occur only at around 30 cm from the anode. Power requirement is approximately 2.5 kVA hence a 2.7 – 3.0 kVA generator is required, amperage will be c. 6 amps. The benefits of using a larger team and two anodes and cathodes are considered but as the fish holding area is restricted to a relatively narrow run, single anode is preferred. A double anode and cathode would place the power requirement for DC fishing beyond the capacity of a portable generator.

Case 3.

The site is a lowland river around 20 metres wide with little flow and uniformly 2 metres deep with a shallow berm in each margin with some macrophyte growth. Water is fairly turbid with visibility only c. 60 cm. Conductivity is high, c. 1000 µs/cm. Width coverage of the site is an issue but launching of a boomboat is impractical due to steep, high floodbanks. The intention is to create a large electric field but not to stun fish so far from the boat that they cannot be seen. Species present are mixed coarse fish and eels.

Approach is to use a punt controlled by ropes pulled by team members on each bank. Two 60 cm anodes are deployed, one at each end of the punt, and two 3 m cathodes are used. Power demands and the tendency to herd shoals of cyprinids preclude use of smooth DC. Pulsed DC at 150 Volts, 30 Hz and 10% duty cycle is favoured. Using these settings the power requirement is around 600 watts, however it is important to have sufficient capacity to be able to turn up the duty cycle and hence current in case difficulties are experienced in catching fish. Hence a 2 KW generator should be used. Nominal attraction fields around each anode will be around 100 cm for attraction and 45 cm for immobilisation.

9. Summary.

- Always measure ambient water conductivity
- Always ensure that there is enough power (generator/control box combination, or batteries) to supply the configuration which has been chosen for the field conditions
- Don't survey in extreme water temperatures, especially high temperatures (16-18 ° C for salmonids, 24 –26 ° C for cyprinids.)

Voltages (assuming maximum effective capture field is desired)

Conductivity (µs/cm)	Applied Voltage (V) – Pulsed DC	Applied Voltage- (V) - DC
< 150	250 – 300	300 - 400
150 -500	200 - 250	250 - 300
500 - 800	150 - 200	-
800 - 1000	120 - 180	-
> 1000	100 - 150	-

Frequencies (For optimum combination of attraction, immobilisation and welfare)

Species	Pulsed DC frequency (Hz)
Salmonids	40 - 60
Cyprinids	30 - 50
Percids	10 - 40
Pike	30 - 50
Eel	10 - 40

NB – for all species, use smooth DC whenever it is practicable.

Duty cycle / pulse width

Conductivity (μs/cm)	Duty Cycle (%)
< 150	10
150 -500	10 - 20
500 - 800	10 - 30
800 - 1000	10 - 40
> 1000	10 - 50

NB always start fishing with duty cycle/pulse width set at the minimum, do not use values > 50%

Anodes and Cathodes.

- Always use largest anode that is practicable; avoid use of very small anodes
- 60 cm diameter anode 10 mm gauge recommended size for
- Don't fish with anodes held close together (<3m for large ones)
- Always use a cathode that has larger surface area than anode
- 3 metre x 25 mm braid; or 75 cm x 75 cm expanded mesh or plate is recommended size
- If surface area of anodes is increased, cathode surface area should be increased by at least the same factor. Use of multiple cathodes is preferable

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