SFCC
The Scottish Fisheries Co-ordination Centre

TRAINING MANUAL

FISHERIES MANAGEMENT
SVQ LEVEL 2:

CATCH FISH USING ELECTROFISHING TECHNIQUES

Inverness College UHI

Last Updated April 2014

INDEX

Disclaimer

Under no circumstances will the Scottish Fisheries Co-ordination Centre (SFCC), its members and/or Inverness or Barony Colleges accept responsibility for any kind of problems arising from the use of the protocol.

Health and safety issues relating to electrofishing are entirely the responsibility of parties who are intending to use or who are using the protocol. Users should bear in mind that electrofishing is a potentially dangerous activity. It is the responsibility of parties using or intending to use the protocol to inform staff of potential dangers and to establish procedures to minimise risks. Under no circumstances will the SFCC, its members and/or Inverness or Barony Colleges be held responsible for death or any form of injury, damage or loss occurring during or as a result of the use of the protocol.

In addition to the risks associated with electrofishing *per se*, personnel working in the vicinity of rivers should be made aware of Weil's Disease (*Leptospirosis*) and other potential hazards and the steps to take to minimise the risk of exposure (Appendix 1).

Acknowledgements

The SFCC would like to thank the Environment Agency for granting permission to adapt and use their electrofishing training material in the SFCC training courses. A large proportion of the electrofishing theory text and diagrams presented here has been obtained from this source. Many thanks also to Galloway Fisheries Trust, the Environment Agency and Marine Scotland Science's Freshwater Laboratory for providing photographs for the training course.

This Introductory Electrofishing manual was reviewed in 2006/7 against current best practice and requirements, and the Bibliography was updated with relevant sources of information. The SFCC would like to thank all SFCC member biologists and Marine Scotland Science staff who contributed to the review and Helen Bilsby for expanding information and completing the revision.

Abbreviations

The following abbreviations have been used in the text:

AC	Alternating Current
DC	Direct Current
PDC	Pulsed Direct Current
SDC	Smooth Direct Current
SFCC	Scottish Fisheries Co-ordination Centre
SVQ	Scottish Vocational Qualification

1. Introduction

1.1 Background

This manual has been prepared as a supporting document for the SFCC introductory electrofishing training course, which has recently been developed to match the standards of the SVQ Level II unit Catch Fish using Electrofishing Techniques. The course provides a basic understanding of the theory of electrofishing, and of the health and safety issues associated with electrofishing surveys, as well as practical experience of using the SFCC protocol in the field.

The electrofishing protocol represents a consensus view by SFCC members on the best way to obtain quantitative and qualitative population estimates of juvenile salmonids in small to medium sized streams. Use of electrofishing for other tasks, including stock assessment in main river stems, stock assessment of other species, removal of unwanted species, fish cropping, broodstock capture or electrofishing from boats are not covered by the course.

A team leader electrofishing course provided by the SFCC covers the considerations to take into account when designing surveys, and data collection using the SFCC protocol.

1.2 Why Fish are Caught for Fisheries Management

In fisheries management, electrofishing is used as a sampling method. Electrofishing is particularly useful in situations where other techniques, such as netting, may be ineffective due to the nature of the species you wish to capture, the "target species", or the habitat. For example:

- Some fish, such as eels are difficult to catch and some habitats, such as fast flowing water, weed beds and rocky shores are difficult to sample.
- Electrofishing gear can either be used to catch fish directly or influence their capture by enhancing other methods.
- Electricity can also be used for non-capture related purposes.

The efficiency of electrofishing in terms of the proportion of a fish population that can be caught varies considerably from site to site, according to a variety of factors.

1.2.1 Capture related purposes

Qualitative Sampling

Qualitative sampling is the capture of representative specimens, and is used to determine their presence or absence. This is the most easily completed electrofishing operation. Typical purposes of such investigations include studies of:

- distribution and movements of fish,
- taxonomy,
- morphology,
- growth rates,
- feeding habitats.

Quantitative Sampling
The quantitative study of fish communities can provide information on:
- numbers,
- biomass,
- age composition,
- year class strength,
- production of the species being investigated.

The assessment of population density and age structure are the main aims of quantitative sampling, which therefore requires a more structured approach than qualitative sampling. Methods in common use include those based on several fishings of the sample area, with the fish caught in each fishing not returned to the sample area until the fishings are completed (removal method), and those based on standardising the amount of electrofishing effort used (timed fishing method).

Decisions on what type of assessment and sampling method will be used are determined by the purpose of the survey, and will usually be made by the fisheries manager or other relevant person.

1.2.2 Removal of unwanted species

You may have seen electrofishing operations quoted as a method used to remove unwanted fish. There are various objectives for carrying out such work:
- Water bodies may need to have all fish removed in order to prepare habitat for subsequent stocking out of eggs or fry of a valued species.
- Trash fish (low value or unwanted fish) may be present in undesirable numbers and therefore need to be removed and possibly destroyed.
- Quality fish may also be present and unwanted because they are in the wrong style of fishery.
- A desired species may simply have reached an unacceptable level of stock density.
- Predator removal is one of the most common exercises when removing unwanted species, but in open systems (non-enclosed lochs or lakes, and rivers) regular fishing may be necessary to effectively control numbers.
- Electrofishing may also be used selectively to capture sick or distressed individuals.

Cropping is the opposite to the removal of unwanted species. It is the removal of wanted species, generally for transplanting or sale, and many species may be cropped commercially.

Fish rescues also fall into this category, although in these cases, cropping is driven by the need to save a population from pollution or other disaster.

1.2.3 Collection of broodstock

Breeding fish stocks usually requires the removal of brood fish from either holding ponds or the wild, and electrofishing may be used. It is a method that can be used to catch gravid (sexually mature) migratory fish as they congregate prior to spawning.

1.2.4 Enhancement of other methods

The purpose of using an electric field is sometimes not to catch fish directly but to enhance the effectiveness of other methods, particularly in larger waters. Seine nets, trap-nets, and trawls can all incorporate component electrodes designed to modify fish behaviour and improve catch rates. Electricity can also be used to stun or kill fish at the point of capture to aid easier handling of large shoals or individuals.

1.2.5 Use of electricity for non-capture related purposes

Although not assessed as part of this course, you may also be interested to know that electricity can have non-capture related purposes on a fishery. This is for information only and should not be tried without advice or suitable risk assessments.

In some situations it is essential to have a screen of some type to act as a barrier or deflector to fish movements. In these cases the use of an electrical screen may be an advantage, especially in running water applications where the flow must not be obstructed. Reasons for the installation of screens or fish fences include:

- Protection of intakes and outlets from entry of fish
- The enclosure of sections of water to isolate sub-populations – the regulation of migratory pathways.

Counting migratory fish as they pass through a river system may also be an objective. Many of the fish counters used for this purpose make use of the fact that the greater conductivity of a fish relative to the surrounding freshwater will distort an electrical field.

Electricity can be used in conjunction with a special holding tank to include electro-narcosis in fish (knocking them out) as an alternative to chemical anaesthesia during transportation, stripping or tagging.

1.3 Legislation Relating to Electrofishing

The current legislation of the Salmon and Freshwater Fisheries (Consolidation) (Scotland) Act 2003 specifies the permissible methods of fishing for salmon (including sea trout) and freshwater fish (including brown trout). Under this Act fishing with electricity is not a permissible method and therefore is illegal.

However, the Act permits exemptions to be made allowing electrofishing for research purposes. Under section 27 the local District Salmon Fishery Board (DSFB), the statutory body with responsibility for the salmon and sea trout fisheries, can grant permission for electrofishing surveys to be carried out on salmon and sea trout waters. In the few areas that do not have DSFBs or where a species other than salmon or sea trout is the target of the investigation or survey, permission is required from the Scottish Ministers.

Permission must also be obtained from the fishing proprietors, and from the riparian owner (if they are not the same persons) to cross their land to gain access to the site.

2. How Electrofishing Works

Electrofishing relies on the creation of an electric field in water to which fish will respond by some form of forced swimming and/or immobilisation, thus rendering them easy to capture. As electricity in water is an unseen force it is not the easiest of subjects to understand, but a good understanding is necessary if optimum and safe use is to be made of the equipment.

2.1 Electricity

Electricity is a form of energy and can be used for performing a task such as running an electric fire, turning an electric motor or, in the case of electrofishing, producing an electric field in water.

2.1.1 Conductivity

Materials that pass electricity are known as conductors, and materials that will not, insulators. Conductivity refers to the ease with which electricity passes through a conductor and is measured in micro-siemens per centimetre (μS/cm). In terms of water, it is the quantity and type of dissolved substances that determine conductivity. For example, water running off insoluble bedrock will have low conductivity whereas rivers draining fertile soils will have high conductivity.

2.1.2 Current flow

Electric current flows through a conductor when there is a movement of free electrons through it and the amount of current flow is measured in amperes (amps).

2.1.3 Electric potential

An electric potential is analogous to a level. Just as a waterfall has to descend from a high to a low level, so electric current flows from a point of high electric potential to one of low electric potential when the two are connected via a conductor. The difference between two points is known as the Potential Difference (PD) and influences the amount of current that will flow. The measurement unit for electric potential is the Volt and the total value is referred to as the Voltage.

2.2 Types of Electrical Current

Two basic types of electricity are encountered: Direct Current and Alternating Current.

2.2.1 Direct current

Direct current (DC) always flows in the same direction and enables positive and negative outputs of a power source to be identified. When the flow is continuous it is known as Smooth Direct Current (SDC). If the direct current is only allowed to pass in short bursts rather than continuously it is known as Pulsed Direct Current (PDC) and the number of pulses per second is the Frequency.

2.2.2 Alternating current

Alternating current (AC) flows in one direction until it reaches a maximum, then decreases and reaches a maximum in the opposite direction. This cycle is repeated many times a second (usually 50) and the outputs of the power source effectively change over from positive to negative with each cycle.

2.2.3 Currents for electrofishing

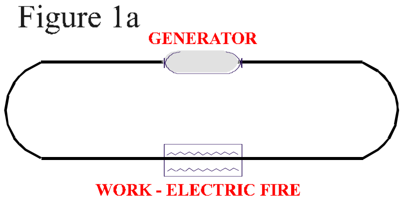
Alternating current is easier to generate than Direct current and the simplest way to produce PDC for electrofishing is to modify the AC. Half wave rectification removes the negative half of the cycle and full wave rectification turns the negative half-cycle into a positive one. Quarter-sine current has not only the negative half-cycle removed but also the leading portion of the positive half-cycle. This is the simplest form of PDC used for electrofishing and it works well as fish tend to respond best to a rapid rise in current flow and a slow fall.

The European and British Standard for electrofishing prohibit the use of AC (Anon., 2003). AC can result in high fish mortality, does not attract fish from cover and also tends to be a greater health and safety hazard than DC. Consequently AC should not be used for electrofishing and will not be covered in the remainder of this document.

2.3 Circuits

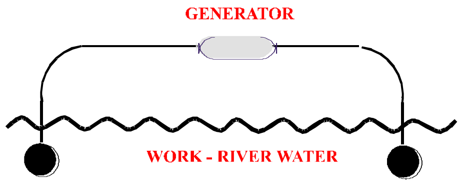
In order to make use of electricity, a circuit is required. In normal circuits in air, great care is taken to ensure that the electricity is confined by insulated wires and cannot escape to where it is unwanted. Figure 1a shows a simple circuit comprising an electrical generator, which can of course be the mains or a portable engine, and a load as represented by an electric fire.

Figure 1a



In electrofishing, only part of the circuit is confined by wire, the remainder of the circuit being the diffuse water path as shown in Figure 1b. Contact with the water is made by means of conductive electrodes.

Figure 1b



For both safety and to enable choice of electricity types, the power source for electrofishing comprises both a portable generator (either batteries or engine) and a control box. Two electrodes are needed as a minimum to complete the circuit. In DC fishing the positive electrode is hand-held and it is known as the anode. The negative electrode, the cathode, is physically different and is often a metal plate or braided copper strip. These typical components are shown in Figure 2.

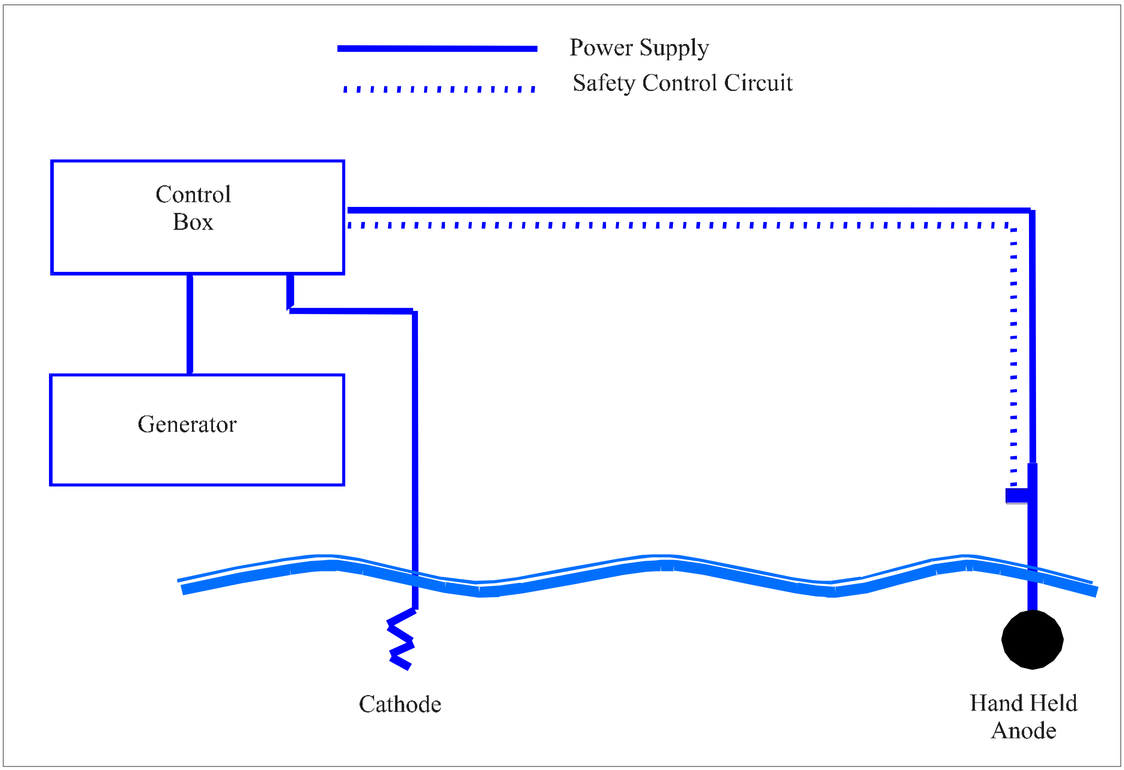


Figure 2. Typical components of electrofishing equipment

2.4 Electrical Pathways in Water

When electric current flows from an electrode into a body of water, it spreads out to occupy much of the available volume in a way analogous to that of magnetic field lines surrounding a bar magnet. The lines of current flow leave one electrode from all surfaces (but are concentrated at sharp corners) and radiate out into the water medium before converging and flowing back into the other electrode. The amount of electric current flowing from one electrode to another is independent of the distance they are apart.

2.5 Action of Electricity on Fish

An electric current will flow through a fish if a detectable potential difference exists between one end of it and the other, and the larger the voltage the greater the current flow. If the voltage is measured for increasing distances away from an anode, it is seen to drop. This is shown in Figure 3, which represents an anode with constant voltage lines drawn around it.

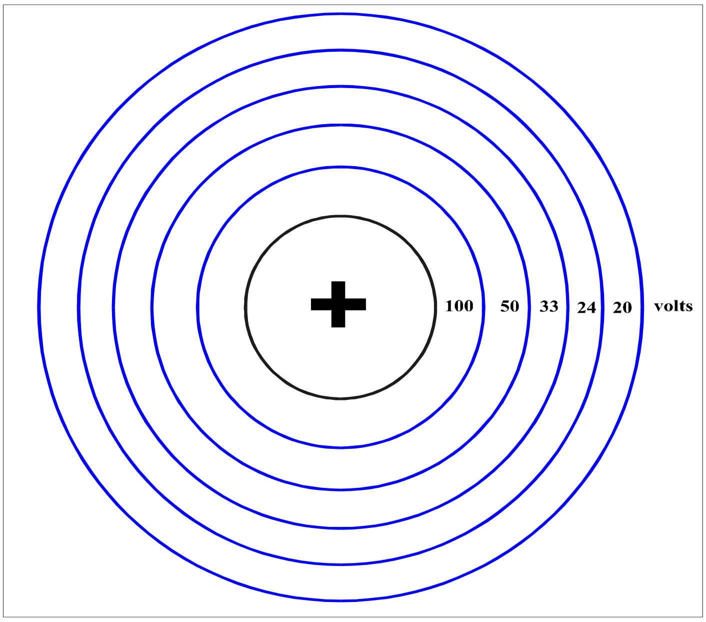


Figure 3. Constant voltage lines around an anode ring

Figure 4 shows an electrode with two fish, one further away than the other. From the voltages measured, the furthest fish experiences a potential difference of 4 volts and the nearest one, 50 volts. There is consequently a zone around the anode which can affect the fish and outside of which the voltage is not sufficient to stimulate the fish. This zone is known as the sphere of influence or the effective electrofishing range.

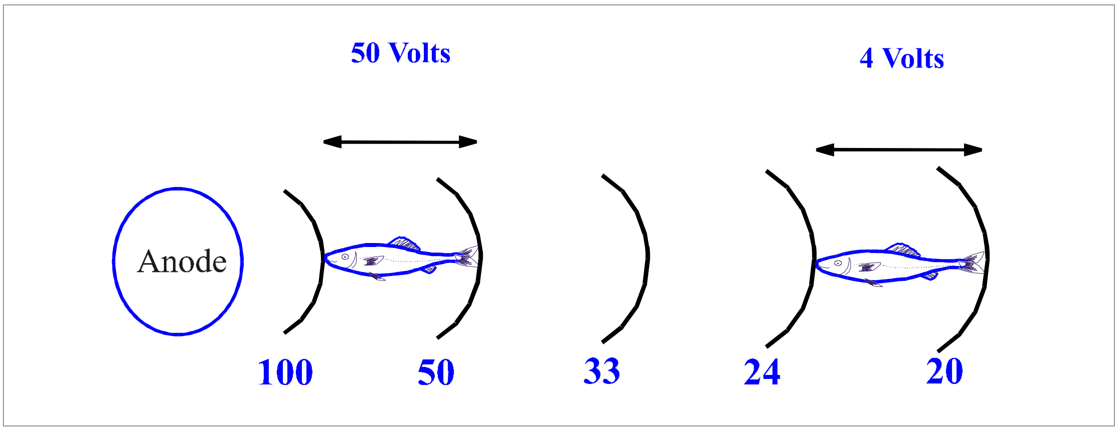


Figure 4. Voltage across a fish

As a fish gets nearer to an electrode and the amount of current flowing through it increases, there are distinct changes in behaviour. All reactions result from inducing electrical stimulation of the fish's nervous system, which at its simplest, can be broken down into sensory nerve paths, brain nerve paths and motor nerve paths.

Fish reaction to electricity depends on both the current type and the fish starting position in relation to the hand-held electrode. There are two current types to be considered, namely smooth DC and pulsed DC, and three fish starting positions relative to the electricity: facing towards, away from and sideways on to the anode.

2.5.1 Reactions to smooth direct current

Fish facing towards the anode:
When the fish is initially facing the anode, fish behaviour falls into 6 major categories. Relative to increasing current flow (i.e. as the fish gets nearer to the electrode) there is indifference, inhibited swimming, forced swimming, narcosis, pseudo-forced swimming and tetanus. These behaviour patterns occur in concentric zones around the anode.

The outermost zone of indifference is where current flow is inadequate for stimulation of the fish's nervous system.

Inhibited swimming is the result of current flow through the fish which, although not enough to stimulate the sensory nerves, blocks the brain message that would normally give a swimming command. This reaction in essence prevents a fish from escaping once it is in the electrical sphere of influence.

Assuming the anode is then moved closer to the fish, forced swimming toward the anode results from stimulation of the sensory nerves which, by reflex through the brain, send a swimming command down the motor nerve pathway.

This action brings the fish into the narcosis zone where, in a similar way to the blocking of the fish’s own brain command, the reflex message is now blocked and forced swimming ceases. (By using special electrodes in a tank and adjusting current flow through fish to be equivalent to this zone, electrical narcosis can be used to facilitate tagging, instead of using chemical anaesthetics.)

In the field, the narcosis zone may not be observed, as the momentum of the fish carries it through into the pseudo-forced swimming zone. Alternatively, as is likely in fast flowing water, the fish is washed back to where forced swimming recommences and the cycle is repeated until the fish tires and is lost.

With the fish even closer to the anode, pseudo-forced swimming is induced by the electrical current now being powerful enough to stimulate the swimming muscles via a spinal reflex from the sensory nerves through to the motor nerves. As the brain is no longer involved in the electrical pathway the fish is seen to be unbalanced during pseudo-forced swimming.

Very close to the anode, the motor nerves are excited directly and to a degree where muscle cramp (tetanus) sets in and the fish keels over.

Fish facing away from the anode:
When the fish is initially facing away from the anode (and thus toward the cathode), 4 major reactions can be identified as the fish gets nearer and current flow through the fish increases. They are indifference, spasmodic swimming, half turn to the anode and tetanus and can again be represented as occurring in zones around the anode.

Indifference is replaced by spasmodic swimming as the anode is moved closer, with motor nerves becoming stimulated directly. It is at this stage that a fish can be lost as it can easily swim back into the indifference zone whereupon it will usually flee.

It is therefore vital, when the fish is initially facing away, to bring the anode close enough for the fish to experience sufficient current to induce the reaction of half-turn to the anode. This is brought about by electrical stimulation of the most anterior sensory nerves which by brain reflex causes motor nerve commands of such a nature that the fish swims round to face the anode.

Once the turn is complete, fish behaviour becomes similar to the final stages already described. Tetanus sets in by the same mechanism.

Fish sideways on to the anode:
When the fish is initially sideways on to the anode, the potential difference is across the fish and not along it. Therefore the fish has to be much closer to the anode to have sufficient current pass through it to induce a reaction.

This occurs in a position corresponding to just outside the tetanus zone and only one behaviour pattern is observed. The motor nerves on the positive side of the fish are stimulated directly, causing muscles on that side to contract and the fish bends toward the anode, a process known as anodic curvature.

2.5.2 Reactions to pulsed direct current

With pulsed DC, when fish are initially facing away from or sideways on to the anode, behaviour is substantially the same as described above for smooth DC. However, for fish facing the anode there is poorer stimulation of forced swimming and a greater degree of narcosis and tetanus. As a result, pulsed direct current can be more injurious to fish than smooth direct current.

2.5.3 How can electrofishing operations/equipment damage fish?

Electrical damage
Electrofishing, when carried out in an effective way so that fish are not subjected to tetanus for long periods, does not kill or permanently injure fish. However, if the electric field is too intense, or of an unsuitable type, or the fish's exposure time to the electric current is too long, then paralysis can follow tetanus. This results from total physiological exhaustion of the nervous connections and pathways within the fish, or physical damage to the fish, and should be avoided at all costs.

Fishing using Direct Current (DC) tires the fish the least and Alternating Current (AC) the most. This is reflected in the recovery times, and risk of injury to the fish, which increase from smooth DC through pulsed DC to AC. Because of the higher risk of injury to the fish or operators than with other types of power, AC electrofishing is not used in the UK.

If a fish comes close to an electrode a semi-permanent discolouration, which looks like a burn or brand, can result on the body. This may be due to direct contact with the electrode or melanophore (pigment cell) dilation in response to nerve damage. Whilst the external branding will disappear, it is often associated with spinal injuries or haemorrhages under the skin. Internal damage may be present in the absence of external signs (Snyder, 2003).

Broken backs or spinal damage may also be an occasional problem if the intensity of the electric current is too great or if spikes of excess voltage occur, as this can cause the swimming muscles on both sides of the spine to contract at the same time. Such damage can be minimised through preferential use of smooth direct current, using the lowest effective power setting, avoiding switching the power on and off when fish are near the anode, and by minimising the exposure time through efficient hand netting of the fish.

Non-electrical damage

During electrofishing operations, fish can also be damaged by factors not directly related to the electric current. These could include:

- Persons conducting electrofishing operations trampling on stunned fish
- Poor netting practice causing damage to fish by banging and squashing
- Chemical damage caused by over-anaesthetising fish or a spill of another chemical into the holding bucket
- Asphyxiation of fish through overcrowding or overheating of the water in the holding buckets.

Damage and disturbance can also be caused to other species sharing the same environment, for example:

- Trampling on freshwater pearl mussels
- Disturbing birds and otters.

3. Electrofishing Field Guidelines

To produce meaningful results for an electrofishing survey it is necessary for staff to work as a team and employ a method that is suitable for the prevailing environmental conditions.

3.1 Typical Electrofishing Team

A typical electrofishing team consists of one team leader and at least one other experienced member of staff. However, this should be seen as the minimum requirement and is only acceptable if certain health and safety conditions (see Section 6) are met. It is advisable that an electrofishing team consists of three people if a single anode is being used and upwards of five people if two or more anodes are being employed. Not more than one inexperienced person should form part of an electrofishing team. This will ensure that the survey is conducted safely and efficiently.

3.2 Typical Electrofishing Equipment

There are two main types of electrofishing equipment currently in use in Scotland: backpack and bankside equipment. Both sets of equipment include a power source, control box, at least one anode and a cathode.

3.2.1 Power source

For backpack equipment the power source is always derived from a battery, usually combined in the same housing structure as the control box. For bankside equipment a dedicated generator is used to energise a separate control box. Each control box then supplies power to at least one anode and the cathode.

3.2.2 Control box

The control box has two distinct functions: firstly, to provide a safety feature that can be used to stop the supply of power to the electrodes, and secondly, to modify the electrical output to the anodes. Control boxes, both backpack and bankside, vary in design but usually comprise the following control features:

- Power on/off switch
- Method for setting the type of electrical output
- Method for changing the level of voltage
- Emergency stop button
- Voltmeter
- Ammeter

3.2.3 Electrodes

The anode is usually hand-held with the live electrical surface at the end of a long insulating tube. The anode is controlled through the use of a low voltage deadman's switch, operating from an electrically independent circuit switch. This switch needs to be consciously depressed for power to flow from the control box to the end of the anode.

Anodes can be used singly or in pairs depending upon the width and morphology of the river. Backpacks only have a single anode.

The cathode is usually a braided metal strip or plate that is placed in the water and connected to the control box via an insulated wire.

3.3 Ancillary Equipment

Ancillary equipment includes all items associated with catching fish during the survey: buckets, hand nets, banner nets and stop nets. Buckets and hand nets are self-explanatory and are used for the catching and holding of fish. Nets should be made from knotless mesh for fish welfare reasons (Anon., 2003).

A banner net is a hand-held net that has been stretched between two non-conducting poles to form a scoop that fish are swept into. It is of use in fast flowing sections of water to catch fish that would otherwise be missed with a hand net.

Stop nets can be used to isolate a population of fish within a section of river. The nets are set at the top and bottom of the section of river to be surveyed in such a manner that they form a "fish tight" seal to stop any fish entering or leaving the section being surveyed.

3.4 Electrofishing a Given Site

Prior to electrofishing a site, it is important to approach each survey in a logical manner to ensure the welfare of the survey staff and any fish that are caught. The responsibility for the welfare of the team and fish falls to each member of the survey team. All members of the survey should be aware of the reasons for the survey and the particular tasks that they will be carrying out. On arrival at a river, the section of river to be surveyed should be identified prior to anyone entering the water. Once the site has been selected stop nets, if being used, should be put in place, starting with the upstream net. This is to ensure that fish do no enter or leave the site, leading to a misrepresentation of the population present.

Following the installation of the nets, appropriate fish holding equipment should be set up. This usually involves the setting up of large buckets/tanks, with or without aeration, or holding boxes placed in the river outside of the area to be surveyed and not subject to the electric field. Ideally the holding buckets should be placed in the shade and covered to prevent excessive water temperatures or fish from escaping.

Once the fish processing equipment has been set up, the electrofishing equipment should be checked to ensure the integrity of the equipment before it is switched on. The start up procedure for electrofishing equipment is detailed in Section 6.

3.4.1 Movement of anodes

In order to effectively electrofish a population of fish it is necessary to bring the fish under the influence of the electric field and to remove them from the water.

Section 2.4 discussed the manner in which the electrical current spreads out from around the anode to form an effective electrofishing zone. Surveys always start at the downstream end of the site so that the flow of water brings stunned fish towards the operator. Starting at the downstream end of the section being surveyed, the anode should be moved in order that all of the fish within the site have an equal chance of coming into contact with the electrical field. The method in which this is done is dependent upon the width and morphology of the river.

The anode should be submerged at all times and held just below the surface of the water. This will help to draw fish up to the surface as they are attracted to the anode, rendering them easier to catch. Figure 5 shows the progression of a single anode up the river encompassing a sweeping movement to ensure that all areas are covered.

Note that it is important to ensure that banks with draped vegetation or undercuts are surveyed as they often contain significant numbers of fish. Sweeping the anode under the banks will help to draw fish out of hiding. If the flow in the river has become divided into a number of separate channels, each channel should be individually electrofished.

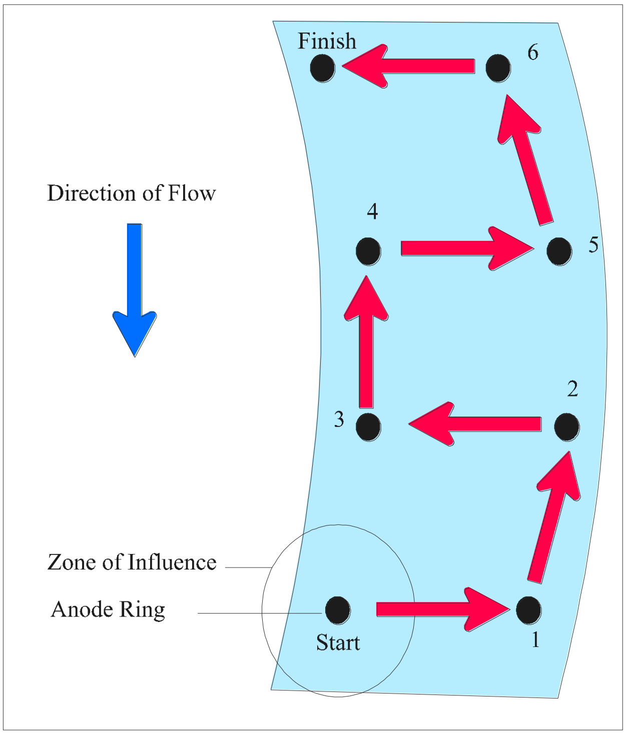


Figure 5. Movement of a single anode across and up a small river

For watercourses less than 5m wide, a single anode can be used to effectively cover the width of the river. The European and British Standard states that in wadeable rivers "As a general guidance one anode per 5m width should be appropriate" (Anon., 2003). Fishing twin anodes in closer proximity increases the current draw on the circuit and reduces the effective range of each anode (Beaumont *et al*., 2006).

For rivers between 5 and 10m in width a single anode may still be effective if the waters being fished are shallow and there is plenty of instream cover to provide fish refuges. **The conditions at the site at the time of fishing should be carefully considered.** Bankside equipment with a single anode, rather than backpack equipment, may be necessary to maintain the power demand required to support an adequate voltage gradient without resorting to a small anode ring. However, if too many fish are noted evading capture, or if analysis of the catch over multiple runs shows an inconsistent or low rate of capture, the data should be interpreted as a minimum density only.

If there is poor instream cover fish are more likely to be aware of the movements of the electrofishing team and will be flushed out, leading to a greater risk of escape and an under-representation of the population. In this case, or where deeper water is likely to result in a smaller effective fishing range, two bankside-powered anodes should be used. Figure 6 shows the movement of the two anodes for a larger river. In order to ensure a representative sample is captured, it is important that the two anodes work together to minimise the risk of fish escaping from the influence of the electric fields.

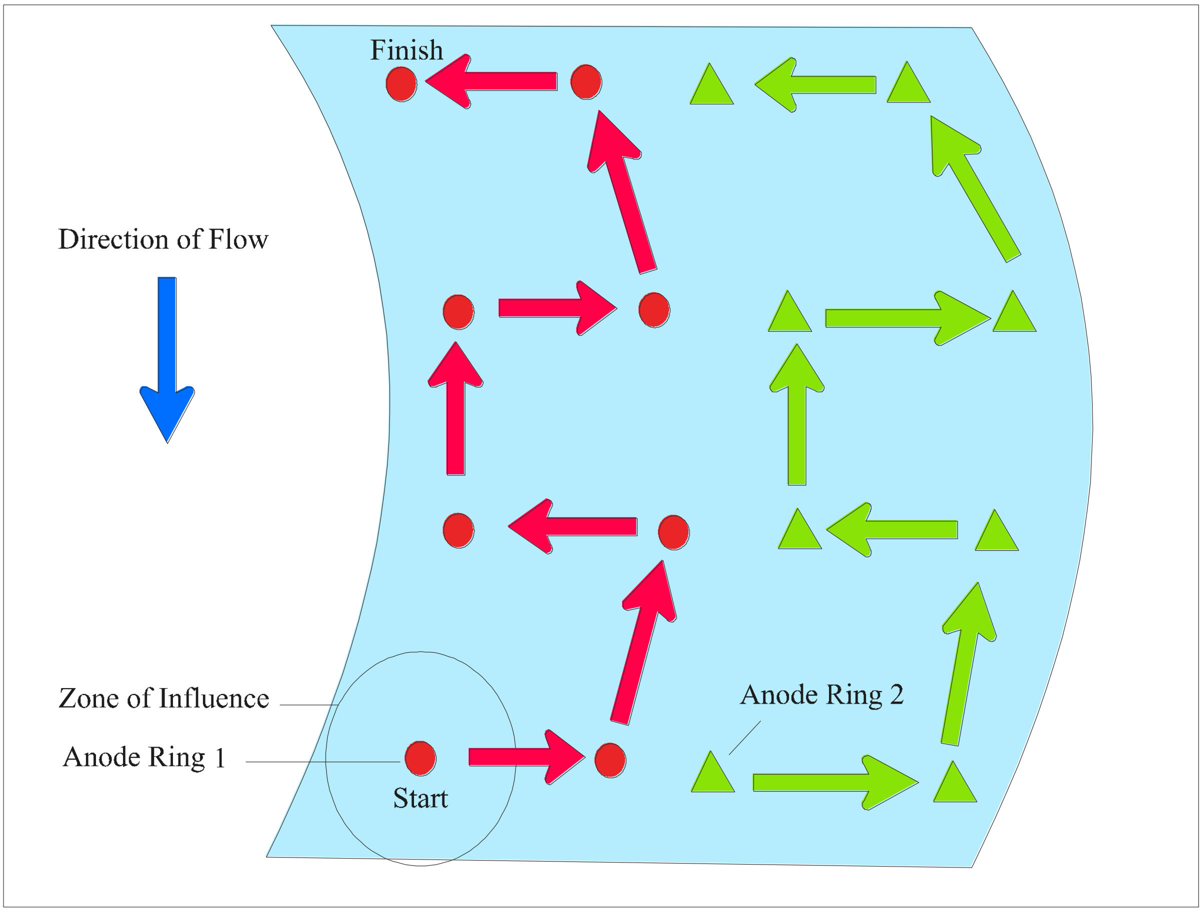


Figure 6. Movement of two anodes working as a team in a larger river

Where bankside electrofishing equipment is being used the same control box directs power to both anodes. Modern safety features ensure the two anodes cannot fish independently of one another, i.e. both anodes must be switched on to receive power and, if one is switched off, the power supply to both stops. The two anode operators should be watching each other and there should be clear communication between these operators and the netsmen to say when anodes need to be switched off or on.

For rivers greater than 10m, with little instream cover, more anodes should be used. Alternatively, where flows allow, the river can be divided into workable widths using barrier nets and each width fished to obtain area-based density data. Another approach is to fish for a given length of time and record the number of fish caught per unit of effort (time).

3.4.2 Movement of nets

The personnel holding the hand nets should follow the anode in such a manner that any fish attracted to the anode can be quickly scooped up and placed in a bucket. This entails placing the net immediately behind the anode ring. If the person controlling the anode can also manage a net then the two nets should be placed behind the ring, one on each side.

Once caught in the hand net, fish should not be left in the water as they will still be within the electric field and subject to potential damage. If a large number of fish are encountered or the netsman needs to pause to transfer fish, the power at the anode should be turned off until all personnel have verbally acknowledged that they are ready to continue.

In situations where it is important to gain a quantitative assessment of the fish populations and the stream bed morphology is suitable, the use of banner nets should be considered. Banner nets increase the effective capture of fry and parr in riffle and glide habitats especially where there are either large numbers of fish present and/or where low conductivity water is a problem, and/or there is poor water clarity.

The banner net as its name suggests presents a “banner” of material across the water flow and the fish drop back into it once stunned. The net is loosely held in position by an operator using two non-conductive poles between which the small meshed banner is suspended. The net is held in position on the bed of the stream by a lead line that prevents fish escaping underneath. The banner netting is approximately 60-70cm deep and the lead line is approximately 80cm long.

Once fish are in the net, the banner is swiftly lifted and the captured fish are transferred to a recovery bucket by another operator using a small hand net. In the hands of trained, experienced staff banner netting can significantly increase the speed at which surveys can be completed. The banner net operates as a temporarily fixed net, and when one is in use, the anode must be used in such a way as to sweep fish into it, which requires practice.

The use of banner nets raises a safety issue in that the operator using the net is holding the two handles of the net just above the water. To avoid the risk of electric shock the operator must keep their hands clear of the water, and the use of rubber gloves is advised.

3.5 Electrofishing and the Weather

Ideally, when electrofishing, the weather would be dry, calm, and not too sunny or warm, so that water levels are at a manageable height for electrofishing and the water stays at a suitable temperature for the fish. A slight breeze is also nice to keep the midges away! However, long periods of weather like this are very rare in Scotland and, during the summer when electrofishing usually takes place, you can be faced with variable conditions. Here are some things to look out for in terms of the weather and electrofishing:

Rain:
- Safety implications: increases the risk of an electric shock from the equipment
- Reduces the efficiency of electrofishing as the rain disturbs the surface of the water and fish become less visible.

The European and British Standard for electrofishing states that "Electric fishing is forbidden when it is raining" without further explanation of the reasoning behind this (Anon., 2003).

The SFCC agrees that electrofishing should not be carried out when rain is likely to affect the efficiency of capture and therefore the validity of the fishing. Also, it is inadvisable to open backpack equipment and expose battery terminals or electrode connections to wet weather. The SFCC advise that electrofishing should not be carried out on days forecast for continuous rain, however on days of intermittent showers electrofishing runs can be carried out in the intervening dry periods. If it starts to rain while you are electrofishing, **consider stopping** the operation and waiting for the rain to pass.

Wind:
- Safety implications: increases the chance of tripping as the operator may be knocked off balance or be unable to see their feet when standing in the water.
- Reduces the efficiency of electrofishing as the wind ripples and disturbs the water surface and fish become less visible. Small fish may also get blown out of nets, particularly if the net is held at an inappropriate angle to the wind.

Consider stopping electrofishing if wind speed is above 15 miles per hour.

4. Factors Affecting Fish Response

4.1 Water Conductivity

By far the most important factor in electrofishing is the conductivity of the water. Figure 7 shows a typical graph of current between two electrodes plotted against conductivity, at a constant voltage. It can clearly be seen that as conductivity increases so does the amount of current flow, i.e. in higher conductivity water there is a higher demand on the power source to maintain a set voltage than for the same voltage in low conductivity waters. However it should be noted that conductivity in turn varies with temperature and changing the size of the electrodes would alter the plotted values.

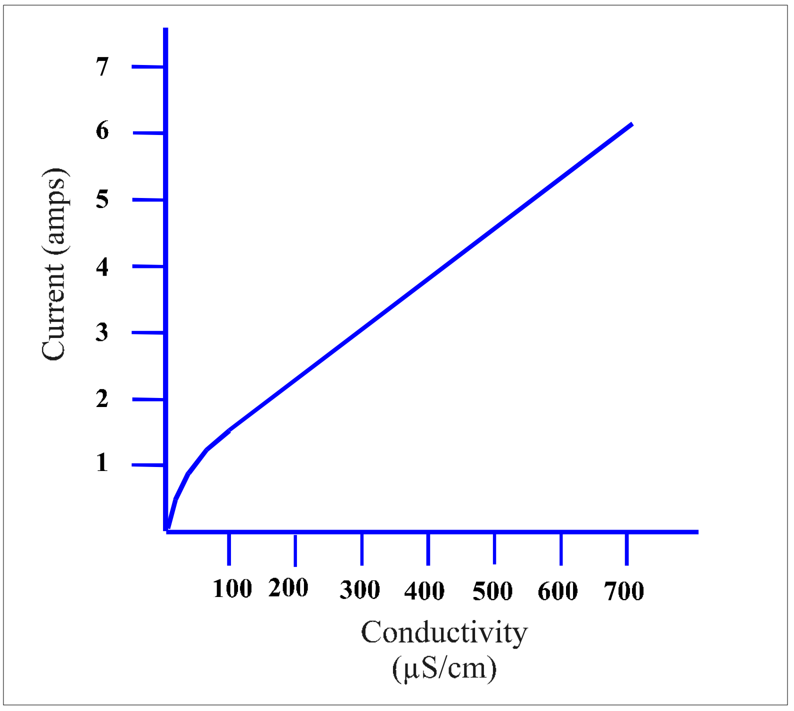


Figure 7. Current passed between two electrodes with increasing conductivity

4.2 Generator Size

For any specific electrofishing set it is the conductivity of the water that decides the amount of current drawn from the generator. By way of example of the principles involved, a 100 watt bulb can be likened to a low conductivity river and a 2 kilowatt electric fire to a high conductivity river. The fire therefore needs a larger generator to work and it is the same with electrofishing. In practice, however, it is sensible from the point of view of handling to use the smallest generator that can supply sufficient power for the job. It is simply fortuitous that inaccessible mountain streams are generally of low conductivity enabling easily portable "baby" generators to be used.

Lower power requirements can be achieved through the use of pulsed direct current as the equipment is discharging current at discreet intervals and not continuously as in the case of smooth direct current. PDC may therefore be useful in higher conductivity waters.

4.3 Electrode Configuration

For any given conductivity, electrode size affects the size of the electrical sphere of influence. An electrode with a large surface area enables more current to flow into the water than does one with a small surface area and it forms a larger electrical field which is less intense close to the electrode surface. Using too small an electrode produces an intense field with high potential gradients which can cause dangerous tetanus effects. Therefore it is desirable to use the largest possible electrode array that stream width and morphology allow, and that available voltage and power allow.

Additionally, often the only way of establishing a reasonable fishing distance in waters of very low conductivity (and hence light electrical load) is to use an electrode of very large surface area to introduce sufficient current into the water to motivate the fish. However, these large electrodes require high voltages in low conductivity waters and generators are often required to supply the power demands.

It should be remembered that, whether single or multiple anodes are being used, the cathode should have a surface area several times the total effective anode surface area. By using a larger cathode than anode the resistance to current flow at the cathode is reduced. This concentrates most of the available voltage at the anode, making more power for fishing potentially available at the anode.

4.4 Current Type

Smooth DC has the lowest tetanising effect, therefore resulting in less injury to fish. It also is better at stimulating fish to swim towards the anode and has the ability to attract fish from hiding places. However the higher power demand to provide smooth DC compared to pulsed DC may limit its use, for instance in high conductivity waters, unless a large generator can be used. Pulsed DC can be used in these situations where smooth DC is not effective, as fish tend to exhibit a greater reaction to pulsed DC compared to the same voltage of smooth DC and the power demand is lower.

The disadvantages of pulsed DC are that it is less effective at drawing fish out from cover and it tetanises fish further from the anode, exposing them to potential injury for longer. Different species of fish react preferentially to different numbers of pulses per second. Table 1 below details the optimum pulse frequencies for a variety of fish based on Beaumont et al. (2002). However not all electric fishing equipment will allow such a precise degree of frequency control. Pulse frequencies should be kept as low as possible whilst allowing effective fishing.

Species	**Pulse frequency (Hz)**
Salmonids	40-60
Cyprininds	30-50
Percids	10-40
Pike	30-50
Eels	10-40

Table 1. Pulse frequencies for different fish species based on the optimum combinations of attraction, immobilisation and welfare.

4.5 Stream Morphology

In large water bodies where the habitat is poor or very uniform and does not restrict fish movement, fish are more likely to escape from the general disturbance and not come into working range. In general terms, therefore, effective electrofishing is more easily achieved in smaller rivers and streams.

Stream morphology also has an impact on electrofishing efficiency by affecting current flow. The electric field is often distorted in shallow water, which allows more effective fishing. In deeper water, where the current lines are more dispersed, power requirements to maintain a given voltage are higher. In high conductivity waters, small generators can sometimes be heard to "die" in such situations particularly when smooth DC is in use.

4.6 Temperature

Fish metabolism is modified by water temperature and consequently fish response to an electric field can change. Fish excitability is increased in very warm water and reactions are reduced in very cold water. In practice this means that in both extreme situations fish become difficult to catch. In addition, fish in warm water are more easily stressed by all the associated handling. For salmonids the best fishing temperatures are l0-l5°C and for cyprinids, 10-20°C. Electrofishing, for juvenile salmonids, may become ineffective when the temperature falls below 8°C, particularly when PDC is in use, as many fish go into hiding and may fail to be attracted to the anode, resulting in quantitative data that underestimates the number of fish.

4.7 Fish Species and Size

For a DC current equivalent to that required for a swimming reaction, the lifestyle of the species can modify response. Salmonid fish are better swimmers than many coarse fish and will therefore swim both more rapidly and for a longer time before becoming exhausted. Bottom living fish such as the bullhead may show a tendency to be immobilised *in situ* underneath stones on the riverbed. Eels in open water will react by swimming forward but one in hiding can react by moving farther back. Shoaling fish species will be more likely to flee than territorial species.

Large fish show a greater reaction to electrofishing than small ones do. The bigger a fish is, the more constant voltage lines it can span, and the higher the potential difference it experiences between head and tail. If it is anticipated that large fish will be encountered, for example during broodstock collection, the voltage must be reduced to the minimum required to attract them. If the large voltages typically employed for juvenile surveys are employed for large fish then injury may occur.

4.8 Operator Efficiency

Practice in field technique is most important as fish can be lost simply by lack of experience on the part of the operator.

In a lot of survey work the aim is to make a good estimate of the stock present. The removal method of fishing is the most popular method, but good population estimates depend on the same effort being put into each fishing run. Each run should be fished by the same people who should fish in as identical a way as possible each time. So many variables contribute to the success of electrofishing that at least the risk of introducing error by lack of constant operator efficiency should be removed.

4.9 Visibility

Irrespective of all other factors, if the operator cannot see to retrieve fish then efficiency is bound to suffer. Major problem areas are waters having high turbidity, wind action, rain or excessive weed growth. The general rule of thumb for juvenile surveys is that you must be able to see the stream bed, otherwise stunned fish may be left behind, resulting in their injury and /or failure to catch them.

5. Post Capture Care and Environmental Conditions

5.1 <u>Post Capture Care</u>

Once the fish have been captured using electrofishing, they should be transferred from the buckets into a suitable holding facility. These may be bins filled with water or holding boxes.

5.1.1 Holding boxes

A holding box has holes in it to let the water flow through, and is covered in mesh to prevent the fish from escaping once in the box. It is placed in the water in an area which will not be affected by the electrical current, and with a gentle water flow through the box. It should have a heavy lid to prevent the fish from jumping out and to help keep the box stationary. Using holding boxes keeps the fish in the same environmental condition from which they were removed and minimises the need to inspect the fish whilst they are being held. They are the best option for holding fish.

5.1.2 Fish holding bins

There is no standard size for fish holding bins, but they should be large enough to hold the number of fish that you anticipate catching. Large and small fish can be held separately to prevent the water becoming rapidly deoxygenated, but for all sizes care should be taken to avoid holding too many fish in the same container. The bins should be placed in a suitable location, preferably on flat ground and in shade, before electrofishing actually begins. The bin should be filled with fresh water from the body of water that you are actually sampling. An aerator may also be used to keep the water oxygenated.

Try to keep bins in the shade and use some form of lid, to protect the water and fish from direct sunlight and to prevent an excessive rise in the water temperature. If the water temperature starts to rise excessively and fish start to show signs of stress due to lack of oxygen, remove some of the water from the bin by decanting using a bucket and replace with fresh cold water from the water body being sampled.

The critical temperature limits for fish survival depend on the species so it is important to know the environmental limits of your target species. Eels should be kept in a separate holding unit as the mucus that covers their skins can irritate and damage the gills of other fish species.

5.2 <u>Recognising Signs of Stress in Fish</u>

Section 2.5 gives information on the action of electricity on fish and the damage that can be caused by electrofishing. However, it is difficult to recognise normal signs of stress when fish are stunned as they are effectively anaesthetised.

The fish can suffer from synaptic fatigue when over-exposed to a tetanising electric current. Usually, when this occurs, the fish does not recover immediately and dies because breathing is not re-established.

Throughout the period that fish are retained in the holding units they should be regularly observed for signs of stress, especially those that could indicate that the fish are short of oxygen. Fish will show some signs of stress in holding bins or buckets anyway, because they are removed from their natural environment. Signs of stress to look for that could indicate low oxygen levels include:

- Hyperactivity in salmonids, although many coarse fish may become quiescent
- Very fast movements of gill covers
- Fish come to the surface and appear to gulp air
- Fish start to keel over.

Any unusual activity could be a sign of stress. Fish should be moving around slowly at the bottom of the bucket and breathing steadily at a normal rate.

If you notice a fish is having difficulty or has not re-established breathing after being stunned, and its gill covers are not moving, it may be possible to resuscitate the fish by moving it backwards and forwards in the water, to pass water through the mouth and over the gills. This stimulates ventilation, starts the heart and starts breathing – the “water flow heart rate reflex”.

Fish should be released once electrofishing and the associated instream measurements at the site have been completed. The fish should be showing signs of recovery – normal activity – and be maintaining their position and orientation constantly in the water column.

If electrofishing has been conducted for survey purposes, the fish should be released into the same area from where they were captured, with no extreme changes in temperature. The fish should be spread out along the survey stretch in areas of calm flow near the bank.

If the fish are showing signs that they are having difficulty recovering in the holding bins, they should be returned to the stream or burn, once electrofishing has finished, and be allowed to recover there. Make sure that they are placed in a sheltered area with a low water flow so that they have time to recover and are not swept away with the current. At this stage the fish may also be more susceptible to predators, so allow fish to recover while you are still around the site and, by your presence, actually deterring predators from coming to the water.

Fish may be retained to identify species and assess growth rates. In this photograph the length of a salmon parr is being measured.

6. Health and Safety

The following Health and Safety section is based on the Environment Agency's Code of Practice for safety in electric fishing operations. In order to complete the Introductory Electrofishing course all participants must successfully complete this section of the course before moving on to fieldwork training. Health and safety is the responsibility of each individual member organisation and no liability will be accepted by the SFCC.

6.1 Personnel

6.1.1 Selection

As with all field work where staff may be working in remote locations, electrofishing staff must be fit for the task that they are being asked to carry out. Personnel should assess their own suitability for the task and, if an individual member of staff feels they have an ailment which may affect their ability to carry out field work, they should inform their employers as soon as possible. Reference should also be made to employer health and safety policies.

6.1.2 Training

No person should take part in electrofishing operations unless all the following apply:

- The theory of how electrofishing works has been properly explained.
- A competent and experienced person has given instruction on the appropriate safe working procedures outlined in this manual.
- Proper instruction is given on the use of any new equipment whenever this is acquired.
- For staff new to electrofishing, a certificate has been received for successful completion of this Introductory course.
- Post training competence can be demonstrated.
- Staff with prior electrofishing experience should be familiarised with the SFCC protocol and this manual in order to highlight any differences from previous techniques.
- 'Refresher' training is undertaken by <u>all</u> staff involved in electrofishing

Personnel involved in electrofishing should be trained in Cardiopulmonary Resuscitation (CPR) techniques. A first aid kit and guidance notes on CPR should be taken on all field work surveys.

6.2 Personal Equipment

6.2.1 Clothing

The employer of those engaged in electrofishing must provide appropriate protective clothing.

Clothing worn for electrofishing should be appropriate to the conditions and should not be so long as to trail in the water as this could introduce an electrical hazard from stray current paths. Clothing should not have buttons or buckles that could snag on cables and landing nets or have metallic zips that could conduct electricity.

6.2.2 Boots

Operators must always wear rubber boots in good condition. If studded boots are needed to avoid slipping, the studs must not penetrate the sole of the boot so far as to destroy its insulating properties.

6.2.3 Chest waders and dry suits

Chest waders and dry suits made from non-conductive material provide a useful means of staying dry but they must not be used without protecting against their potential hazards with respect to drowning. If the average depth of water is too deep for operators to wade at less than thigh depth for the majority of the fishing exercise, then fishing should be carried out from a boat. Water deeper than hip height must never be waded due to the risk of partial buoyancy causing a loss of footing.

Lifejackets must always be worn during electrofishing. Chest waders must not be worn in boats. The only permissible exception is when fishing with hand-held electrodes in inland waters (excluding estuaries) where the operators need to embark and disembark whilst fishing, e.g. when sampling a riffle and pool site.

6.2.4 Lifejackets

Lifejackets must be worn at all times during electrofishing by anyone associated with the water. For general purposes the lifejacket must have a buoyancy of 150 Newtons and comply with the British Standard BS EN 396:1994. For marine and estuary work the lifejacket must have a buoyancy of 275 Newtons and comply with British Standard BS EN 399:1994.

6.3 Electrical Equipment

All components of the electrical equipment must be suitable for exposure in a wet outdoor environment. Particular attention must be given to standards of enclosure, robustness, construction, mounting and electrical protection of components, terminations, plugs and sockets. All equipment must be manufactured in accordance with the Environment Agency *Electrofishing Equipment Specification Annex A.* Although full details are given in the *Equipment Specification,* users should be aware of the following general requirements.

6.3.1 Protection

The minimum specification must be IP 57 for switches, cable glanding and connectors on electrodes and IP 55 for the control boxes.

(IP Index of Protection: 1st numeral, 5 = protected against ingress of dust,
2nd numeral, 5 = protected against jets of water from all directions,
2nd numeral, 7 = protected against the effects of immersion).

Each piece of electrofishing equipment must be marked with appropriate warning signs, as defined in *Annex A.* These include a black edged yellow triangle with the zigzag electricity symbol in black to indicate the potentially hazardous nature of high tension electricity.

6.3.2 Power supplies

Power must not be fed directly from the power source to any fishing electrode, but must be fed via a control box. The control box must be employed to interrupt the current path from the power source to electrodes (whether or not it also modifies the nature of the supply).

6.3.3 Batteries

Batteries must be of the non-spillable, maintenance-free type. Batteries should be in an enclosure separate from the control box.

6.3.4 Generators

The output from the generator must not be earthed but must be isolated from the frame and arranged so that power can enter the water only via the electrodes. As electrofishing generators are not earthed they should not be used for other purposes and should be labelled as such.

The operators must be protected from any electro-mechanical hazard which could be brought about by accidental bodily contact with the generator and its frame. Contact with electrical components, moving parts and the exhaust should be prevented by the provision of appropriate guards, either integral or custom made.

The generator output must be controlled via a manually operated double pole switch. Other than where the control box is mounted on the generator frame, this switch must take the form of a large red button marked 'STOP', which will latch in the 'off' position when pushed.

6.3.5 Mains electricity

Electricity supplied direct from the mains must never be used as the source of power for electrofishing.

6.3.6 Control boxes

Each control box should comprise an independent enclosure, not forming any part of a generator assembly. The control box must be water resistant and made from non-conductive material of high impact strength. All fittings such as handles, control knob and sockets must be of non-conductive material. The power cables supplying the control box should be permanently glanded into the box.

The control box must incorporate visual indication to show when the unit is energised and when power is available at the electrode connectors.

Any knobs, switches or buttons used for adjusting or resetting the control box output whilst in the field must be accessible only on the outside of the housing.

Power must not be fed direct from any power source or control box to any fishing electrode but must be switched on each output by at least one safety control circuit device. The safety control circuit switch (the so-called “dead man’s switch”) must be consciously maintained by the electrode operator and immediately interrupt the power supply to the electrodes when the switch is released. Switching of power must be arranged such that electrodes cannot be energised independently of each other but can receive power only when all persons using an electrode have their safety control circuit switches depressed.

The control box must have a large, red 'STOP' button, which latches in the 'off' position when pushed, to interrupt the supply from the power source to the control box circuitry.

6.3.7 Cables and connectors

All cables must have suitable oversheath qualities to resist damage and be of high visibility.

Power and control circuit cables should not be extended or fitted with connectors of any type except at the control box or at the output from a generator.

Plugs and/or socket connectors used for electrofishing must be kept and wired exclusively for the purpose. A wide variety of plugs and connectors are used by electrofishing equipment manufacturers but all connectors must be non-interchangeable and polarised so that generator, hand-held electrode, cathode and control circuit connectors are separate and not compatible with each other. Industrial waterproof, lockable DIN plugs and sockets which comply with Section 6.3.1 are required. The following colour coding is recommended for plugs and cables to aid identification:

- High power circuit: Control box to generator - blue.
- High power circuit: Control box fishing circuit output to hand-held electrode - blue.
- Low power safety control circuit: Control box safety control circuit to safety control circuit switch on hand-held electrode - white.
- High power circuit: Control box fishing circuit output to cathode - yellow.

6.3.8 Electrodes

Hand-held electrode handles must be made from a tubular insulating material (not wood or material liable to wick) with a suitable stud for the attachment of the electrode head. Connections to the electrode head and safety circuit control switch must be within the tubular handle.

6.3.9 Backpack equipment

Only electrofishing units specifically designed for the purpose can be carried whilst energised. In addition to the requirements outlined above regarding the use of dedicated connectors, safety controls and electrodes, the following rules apply:

- Backpack equipment must be battery powered. In the UK engine driven generators are not permitted.
- The backpack unit must be mounted on a quick release harness to enable rapid removal from the person carrying it.
- The control box must contain tilt and float switches, which interrupt the power input from the battery whenever the unit ceases to be carried less than 45° from upright or if the unit enters the water. These switches must operate electronic trips such that manual reset via the external button is required before the control box can be re-energised.

6.3.10 Boats

When selecting boats for use in electrofishing operations the following points must be considered:

- The boats must be large enough to accommodate both the crew and equipment without overcrowding and must provide adequate flotation consistent with degree of loading.
- The boats must be as stable as possible, taking into account the work activities of the crew. Boat decks should have an anti-skid surface.
- Provision must be made for securing the electrofishing equipment against accidental movement in the boat.
- Boats used for electrofishing must be constructed of non-conducting material, except in the case of commercially-made electrofishing boats designed specifically for the purpose which may use the aluminium hull as the cathode.
- Any anchoring, mooring or shorelines used in conjunction with boats should be non-conducting, e.g. ropes, synthetic fibre and not wire rope or chain.
- All metal surfaces including fuel tanks, toolboxes, generator frame etc., must be electrically connected together.

6.4 Ancillary Equipment

Equipment such as buckets, landing net handles and fish containers, must be made of non-conducting material as far as is reasonably practicable.

Outboard motors should have non-conductive engine covers and have insulated steerage and gear change levers. If this is not practicable then alternative solutions should be considered, e.g. the provision of insulating gauntlets.

6.5 <u>Equipment Use</u>

6.5.1 Manuals

All equipment must have accompanying operation and maintenance manuals which provide full descriptions of the equipment, performance specification, use of controls and safety instructions.

6.5.2 Maintenance

Electrofishing equipment must be properly maintained and regularly checked for mechanical and electrical faults. Service intervals may be related to the degree and conditions of use, but must not be longer than three months for electrical safety maintenance checks and not longer than twelve months for full service of the generator.

Maintenance must be carried out in accordance with the Environment Agency *Electrofishing Equipment Maintenance Specification and Schedule Annex B.*

These regular checks must be performed by suitably qualified personnel who must keep suitable records. To facilitate the keeping of records, equipment items should be individually identified. Safety checks carried out by operators must be considered as an addition to routine maintenance and not a substitute.

6.5.3 Faults

Any fault which is found during inspection of equipment prior to its being used, or discovered whilst fishing, must be reported to the responsible officer. The equipment must be taken out of commission and be clearly labelled with the defect, pending repair.

In the event of equipment malfunction on site, the spare unit should be substituted as control boxes must not be opened in the field.

6.6 Hazards Associated With Electrofishing

6.6.1 Electrical hazards

Electric shocks may themselves injure or kill, or may cause indirect injuries by making a worker recoil so that he endangers himself and others by sudden movement. Direct effects include electrical burns, heart failure or interference with breathing. The main sources of potential risk of electric shock during electrofishing operations are:

- Bodily contact with energised electrodes.
- Bodily contact with water within the radius of the electric field.
- Shocks from damaged, inadequately constructed or poorly insulated equipment.

6.6.2 Other hazards

- Drowning
  When working on or near water there is always a risk of drowning. Lifejackets must be worn (see Section 6.2.4) during electrofishing operations.
- Fire
  Electrofishing equipment powered by petrol driven generators can become hot. When this is the case, the danger of fire must be recognised and suitable fire extinguishers available. Care should also be taken to ensure metal items do not come into contact with backpack battery terminals for example when they are being transported in rucksacks when not in use. A power shortage could cause fire.
- Tripping and falling
  Cables and ropes must be kept clear of machinery and should be routed so as to avoid tripping operators.
- Injuring others
  Operators working where space is restricted should take care not to injure others when using landing nets, electrodes and poles. Operators should be careful not to rock boats, causing others to lose their footing.
- Weil's Disease
  All staff working in or near water should be made aware of the risk of Weil's disease (see Appendix 1).

6.6.3 Internal combustion engine hazards

There must be adequate ventilation. Operators must be made aware of the dangers of concentrations of exhaust gases and where possible keep upwind of engine exhausts.

6.6.4 Manual handling

Serious injuries can result if heavy equipment is not properly handled. The incorrect use of any equipment may result in minor cuts, bruises, grazes, burns and muscle strain.

6.7 Recommended Working Procedures

The method of operation adopted will vary with the requirements of the work, but should always take into account the need to guard against the hazards listed in Section 6.6.

An experienced team leader must be appointed to every team of operators and should have on-site responsibility for safety, first aid and for the equipment and protective clothing. However, every member of the team has a responsibility to work in a safe manner and to inform the leader of any deficiencies. Each SFCC member must issue formal guidance as to the appointment and responsibilities of the team leader. Due to the particular hazards associated with electrofishing, drinking alcohol during the working day should not be allowed.

6.7.1 Size of fishing teams

All electrofishing teams must normally comprise a minimum of three persons. However, teams of operators should be kept as small as practicable for the job in hand. Two person teams are normally acceptable only if all the following conditions are met:

- Back packing with a single electrofishing machine.
- Mobile telephone communication established.
- Both operators experienced i.e. certificated.
- Risk assessment made of the nature of the watercourse.

Not more than one person in the team should be without previous experience of the work. The only permissible exception is when inexperienced users are being trained and are working under the separate supervision of a competent officer, not directly involved with the fishing activity. No-one should ever electrofish alone.

6.7.2 At the depot

Storage of electrofishing equipment must be under secure, safe, dry and clean conditions. After use, all equipment should be returned to storage in such a manner that it is suitable for use on the next occasion.

Prior to the equipment being taken into the field for use, it is the duty of an appointed officer to inspect the equipment, paying particular attention to generator, electrical control gear and cable insulation. An equipment checking schedule should be devised. Simple equipment, suitable for testing whether gear is working or not, should be provided and responsible officers trained in its use. No electrical repairs can be carried out on site and so correct spare units should be carried for equipment that is likely to go wrong.

6.7.3 On site

Portable telephones or radio communications must be provided. On arrival at the site it must be confirmed that such apparatus will work in the desired location. If radio-telephone communication is not possible, the location of the nearest working telephones during the course of travel in the day's work should be known.

Before the start of each day's work the team leader must brief the team on the work to be done and specify the tasks each person has to perform. A clear system of working signals should be laid down before operations begin and followed by all members of the team.

Equipment should be re-checked on site when fully assembled and while electrically dead, paying particular attention to plugs and sockets to ensure that they are correctly fitted and seals fully tightened. A system for checking equipment should be established and followed. This must include checks on the mechanical operation of safety switches before the equipment is energised.

Any item of the equipment must not be used if any part of it appears not to be working.

If the result of the electrically dead examination is satisfactory, the generator should be started to prove the operation of the systems and safety switches with the electrodes immersed in water before actual fishing begins. Fishing electrodes must never be energised unless immersed in water.

Checking operation of safety switches using a circuit test meter whilst equipment is electrically dead.

6.7.4 Spectators

Where fishing activity is likely to attract spectators, temporary warning signs should be erected to indicate ‘Danger, electrofishing in progress’.

Spectators should be warned to keep away from the water and equipment. Animals must also be kept away. Fishing must stop if persons or animals come within five metres of the electrodes.

6.7.5 Start up procedure

Generators should be started and control units energised only when the electrodes are in the water and each team member has verbally acknowledged that they are ready for operation.

6.7.6 Electrical safety

Unprotected parts of the body must not be put in the water when electrofishing equipment is operating.

Any metallic part of an electrode must not be touched unless it is physically disconnected from the electricity supply. Nothing should be taken from the electrode by hand; fish and debris should be transferred to a non-conductive container before being handled.

Whenever the equipment is operating, the electrodes should be treated as being live, even when safety switches are known to be off. Electrodes must not be left unattended when connected to a live power source.

Under no circumstances should the electrode head be allowed to leave the water before the safety control circuit switch is released.

Electrode rings must not be used as dip nets.

The equipment operation manual for each type of fishing gear must be made available to all personnel involved with its use.

6.7.7 Fire and pollution hazards

Smoking must not be permitted in the vicinity of petrol supplies. Petrol tanks should be filled before work begins. A petrol tank must not be filled when the engine is running or hot. A funnel or can with a filler-spout must be used and adequate precautions taken to avoid petrol spills. Spare fuel should be stored and carried in Health and Safety Executive approved containers, at a safe distance from generators.

6.7.8 When working from a bank

The generator and control gear must be secure to prevent them falling into the water. Unless specifically designed for the purpose (see Section 6.3.9) a control box must not be carried while energised. The generator must not be moved when it is running. At all times there must be ready access to the power 'STOP' button. Lifejackets must be worn at all times during electrofishing (see Section 6.2.4).

6.8 Emergency and Accident Procedure

If there is an accident, immediately:

1 - Switch off the electrodes.

2 - Switch off the emergency stop button.

3 - Remove electrodes from the water and stop the generator.

If qualified to do so, administer first aid. Any casualty who has been rendered unconscious must be examined by a doctor as soon as possible, even if he/she appears to have recovered.

In the case of serious injury, call for an ambulance by the quickest available means as this is the fastest way of obtaining medical care. Electrofishing operations are frequently carried out in remote areas with difficult access. In these circumstances, consideration should be given to using on-site transport to move the casualty to the nearest point where medical help can be obtained, but the possible saving in time must be balanced against the risk of aggravating the injury.

Where injuries are minor, apply first aid as necessary. Do not neglect minor burns, cuts and abrasions which should be cleansed and covered with a waterproof dressing.

APPENDIX

Appendix 1: Weil's Disease and Other Health Hazards

Weil's Disease

All personnel involved in working near water should be made aware of the risks o Leptospirosis and the more severe form, Weil's Disease. The disease Leptospirosis is cause by *Leptospira* bacteria and is transmitted to humans by contact with the urine of rats, cattle foxes, rodents and other wild animals, usually by contact with contaminated soil or water. I the UK the most common *Leptospira* bacteria are those associated with cattle and those wit rats.

Bacteria from the urine can survive in fresh water for up to a month and infect animals an humans which come into contact with it. Infected water may not appear polluted, but caution should be applied around water draining farmland or areas of human habitation where rats could be present. Areas where signs of pollution or rats are seen should be avoided.

The bacterium enters the human body through cuts in the skin or through the lining of the nose, throat or alimentary tract. Therefore to minimise the risk of infection cover cuts with waterproof dressings, wear oversuits and gloves, and do not immerse your head. If an area is thought to be low-risk and diving or snorkelling surveys are being carried out, drysuits are preferred and care should be taken to avoid swallowing water when purging or changing regulators / snorkels. Hands should be washed thoroughly before eating, drinking or smoking, and all equipment and clothing should be disinfected or washed in clean water after use.

Weil's Disease is extremely rare in the UK, however it is a very serious illness and must be swiftly diagnosed and treated.

The incubation period for the disease varies from 3 to 19 days. The initial stages of Weil's Disease resemble a cold or flu, with symptoms including **fever**, **muscular aches and pains**, **loss of appetite** and **nausea.** The fever lasts for approximately **five days** followed by a marked deterioration. Later symptoms include **bruising of the skin**, **sore eyes**, **nose bleeds** and **jaundice**. Treatment with antibiotics needs to begin rapidly after symptoms develop. If left untreated it can cause **liver damage** and even **death**.

Anyone experiencing a fever after working in water should contact their GP immediately and tell them that they suspect Weil's Disease. Weil's Disease is a notifiable illness in the UK and if it is confirmed it will be necessary to inform the local Public Health office where you believe the disease was caught. Pocket cards "Working with sewage" (publication IND(G)197) providing readily accessible information can be obtained from the Health and Safety Executive.

For further information visit:
Health and Safety Executive: www.hse.gov.uk/pubns
NHSDirect: http://www.nhs.uk/SymptomCheckers/Pages/Symptoms.aspx/
The Leptospirosis Information Center: www.leptospirosis.org

Other Health Hazards

Field workers should also be made aware of other potential health hazards. These include Lyme Disease and contact with toxic plants such as Giant Hogweed.
Lyme Disease is caused by the bacterium *Borrelia burgdorferi* and is transferred to humans by infected ticks. Care should be taken around forests and heathland where the tick's hosts, sheep and deer, are prevalent. Exposure to tick bites can be reduced by covering the arms and wearing long trousers (light colours show up the ticks most easily) or wellingtons, and by checking your skin carefully at the end of the day. Most ticks are not infected with the *Borrelia* bacterium but it is wise to remove them as soon as possible. Grip the tick as close to the skin as you can with tweezers and gently pull, twisting anti-clockwise at the same time. Specially designed loops for tick removal are often available from pet shops or veterinary surgeries.

The first symptom to be aware of is usually a pink or red spot at the site of the tick bite. This may take 3-30 days to develop and expands steadily, often with an inflamed red border. As the rash spreads the inner skin may return to a more normal appearance, forming an expanding "target pattern" with a flat border, or it may remain more evenly coloured. This rash, the "erythema migrans", may become large (10-70 cm) if left untreated. Additional symptoms in the first few weeks are: tiredness / fatigue, headache, fever, aches in muscles and joints, stiff neck and swollen glands. In rare cases more serious complications affect the nervous system, joints, heart and other tissues.

Anyone experiencing the erythema migrans rash should seek medical treatment. Diagnosis of Lyme Disease can be difficult, especially if you have been unaware of the tick bite, as the bacterium does not always trigger the production of antibodies against it as some forms do not have a cell wall and may fail to be recognised as "foreign". Early treatment with antibiotics is usually recommended.

For further information visit:
NHS Direct: http://www.nhs.uk/SymptomCheckers/Pages/Symptoms.aspx/
British Lyme Disease Foundation www.wadhurst.demon.co.uk/lyme/

Giant Hogweed has a reddish purple stem and spotted leaf stalks, with fine spines that make it appear furry. The plant can grow to between three and five metres in height, the leaves may expand to 1.5 metres in width with flower heads commonly 250mm in width. The sap of giant hogweed contains an irritant which makes skin sensitive to ultra violet light and which can result in severe burns to the affected areas, with swelling and painful blistering. Large, watery blisters usually appear within 15-20 hours of contact with the sap and exposure to sunlight. Damaged skin will heal very slowly and can leave a residual pigmentation which can develop into a dermatitis which flares up on exposure to sunlight.

Recognition of giant hogweed plants and avoiding contact with them are the best means of prevention. Long sleeved clothing should be worn in areas where it is present as this will minimise the risk of contact. Should contact occur with the sap, either through brushing against the bristles on the stem or breaking the stem or leaves, the skin should be **covered up** to reduce exposure to sunlight and washed **immediately** and thoroughly with soap and water.

If eradication programmes are to be implemented, in Scotland the Scottish Environment Protection Agency must be consulted about the proper use of herbicides near watercourses.

For further information visit:

NetRegs environmental guidance:	www.netregs.gov.uk/netregs/processes/367839/
SEPA:	www.sepa.org.uk/

Appendix 2: Electrofishing from Boats

In some cases it may be necessary to electrofish from a boat. This type of electrofishing is not covered by this Introductory Electrofishing course, due, in part, to the additional Health & Safety risk. The course also focuses on electrofishing for the purposes of juvenile salmonid assessment, which usually takes place in burns that are less than 0.5m in depth (thigh depth). The following gives information on when boats may be required to electrofish, the procedures and code of best practice.

Small rivers

Whenever water deeper than thigh depth is to be sampled, a boat should always be used as wading beyond this depth can be hazardous. Operators holding electrodes and dip nets obviously need to place themselves in positions to optimise use of the electric field. It is often advantageous if staff can adapt to using an electrode in one hand and a dip net in the other.

The boat should move downstream in such a manner as to facilitate good coverage of the habitat, or upstream if the flow is high. With smooth DC in slow moving water it is not necessary to match boat movement to water flow, as an attractive field is in use, and the boat can be controlled by ropes from the bankside if required. In more rapid water with both smooth DC and pulsed DC, it is important to allow the boat to travel at the same speed as the water flow, only using outboard motors or paddles for manoeuvring, such that the boat remains close to (drifting) immobilised fish. The larger the river, the more difficult it becomes to set stop nets. With PDC, manipulation of pulse shape and frequency can sometimes improve capture rates for specific target species.

Large rivers and canals

Major rivers and navigable canals are notoriously difficult to electrofish. Seine netting or a similar technique may be a preferred option where the water velocity and nature of the bed allow it. Conventional electrofishing using hand-held electrodes may result in disproportionate amounts of effort for small catches of fish when applied to the large waterway situation. Any attempt to improve capture efficiency must in some way increase the size of the effective electric field relative to the area being fished.

Block nets can be set so as to divide a sample site into separate lanes and keep target fish within range of the electrodes. These block-netted subsections can be fished either in turn or, if several sets of gear are available, simultaneously.

An alternative and obvious route toward enhanced performance of the electric field is to increase the number of catching electrodes. Arrays comprising many pendant electrodes can be mounted on booms attached to the bowsprit of the fishing boat. Current demands by multiple electrodes are high and so very large generators and powerful control boxes may become necessary.

Often, however, it is still only possible to sample the margins with any reasonable degree of efficiency and fish in the deeper water evade capture. Nonetheless, where electrofishing is deemed appropriate, boom-mounted electrodes may provide a suitable and cost effective apparatus for large river systems.

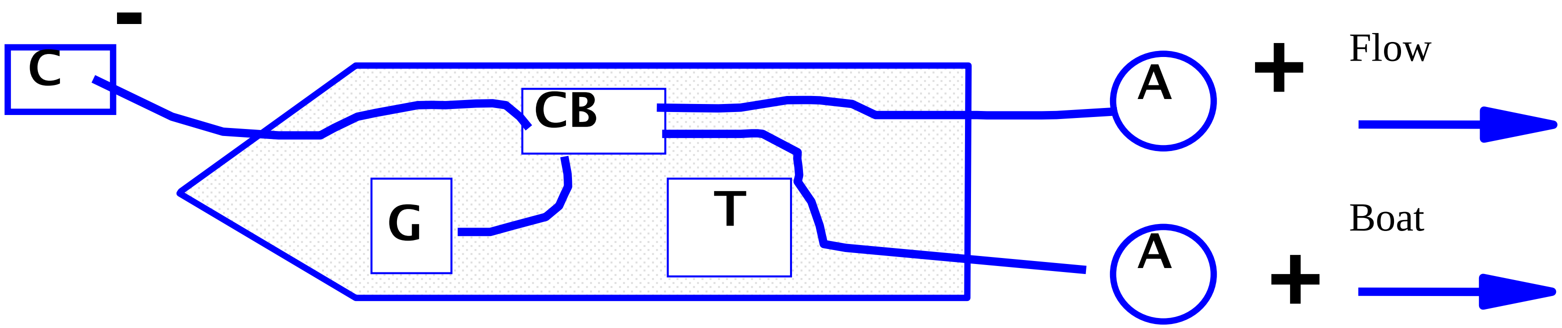
Still waters

The success or otherwise of electrofishing in still waters depends very much on the size of the lake or pond to be sampled and whether or not it has habitat types which can provide refuges for fish. Attempts to electrofish deep, open water shows the method at its worst with fish having unlimited space in which to readily escape from the influence of an electric field.

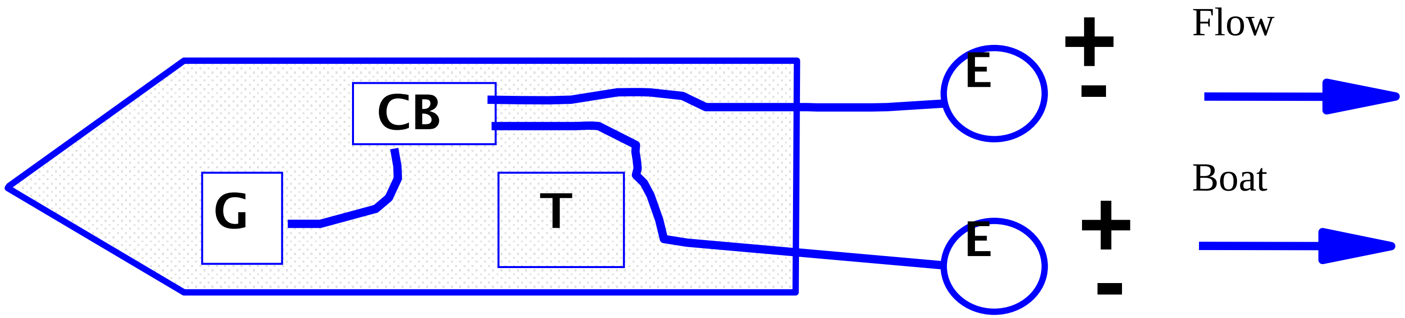
However, good results can be obtained in appropriate circumstances. Conventional hand-held equipment can achieve reasonable success in small ponds or around the margins of larger ones. Big fishing machines with their boom-mounted multiple electrode arrays, as used on major rivers, are well suited to work on large lakes. They can be particularly effective in habitat rich zones such as around underwater obstacles, amongst stands of submerged water plants and along rocky shorelines. Block-netting lengths of shoreline or entire small coves can enhance capture rates.

In addition, for large lakes it is important that serious consideration is given to the seasonal and diurnal movement regimes of the target species and that sampling times are chosen accordingly.

SDC/PDC BOAT



AC BOAT



G = Generator **A = Anode**

CB = Control Box **C = Cathode**

T = Fish Tank **E = AC electrode**

Figure A: Typical boat electrofishing

Code of Practice for Electrofishing from Boats
(Adapted from Environment Agency 2001)

1. Introduction

In shallow streams the operators are likely to wade in the water and use backpack machines or long electrode cables to reach from the portable power source lodged on the bank. In rivers and the margins of still waters, similar equipment is deployed from a boat. In very large water bodies, many electrodes may be suspended from a custom-built boom which is mounted on the bow of the fishing boat. Typical components of electrofishing gear are shown in Figure A.

The equipment most commonly in use at present operates in the order of 200-300 volts and produces outputs of pulsed direct current (PDC) or smooth direct current (SDC). Current may be in the order of 0.5 amp for small electrodes in low conductivity water to 20 amps, or so, for large electrode systems in highly conductive waters. It must be recognised that any equipment producing an effect of this sort is potentially dangerous, but in the case of electrofishing the danger cannot be overcome by containing the electric field as the equipment would no longer work.

When the number of hand-held electrodes being used becomes difficult to co-ordinate, consideration should be given to mounting the electrodes on a boom at the front of the electrofishing boat. Where such boom-mounted multiple electrodes are in use, electrodes should be wired so that the entire array can be operated by means of a single interrupting device as if it were one giant electrode. For such an array, foot controlled switching is recommended. Booms should be of high visibility.

2. Equipment Design Criteria

2.1 Boats

When selecting boats for use in electrofishing operations the following points must be considered:

- The boats must be large enough to accommodate both the crew and equipment without overcrowding and must provide adequate flotation consistent with degree of loading.

- The boats must be as stable as possible, taking into account the work activities of the crew. Boat decks should have an anti-skid surface.

- Provision must be made for securing the electrofishing equipment against accidental movement in the boat.

- Boats used for electrofishing must be constructed of non-conducting material, except in the case of commercially-made electrofishing boats designed specifically for the purpose which may use the aluminium hull as the cathode.

- Any anchoring, mooring or shore lines used in conjunction with boats should be non-conducting, e.g. ropes, synthetic fibre and not wire rope or chain.

- You should also refer to codes of best practice for boat work.

2.2 Chest waders

If the water is too deep for operators to wade at less than thigh depth for the majority of the fishing exercise, then fishing should be carried out from a boat.

Chest waders must not be worn in boats. The only permissible exception is when fishing with hand-held electrodes in inland waters (excluding estuaries) where the operators need to embark and disembark whilst fishing, e.g. when sampling a riffle and pool site.

2.3 Lifejackets

Lifejackets must always be worn when working from a boat.

2.4 Other hazards

Operators should be careful not to rock boats, causing others to lose their footing.

3. When Working From a Boat

- All members of the electrofishing boat crew must be familiar with the principles and practice of safe boat handling.
- The generator and control gear must be securely fastened to prevent movement. At all times there must be ready access to the power 'STOP' button. Energised control boxes must not be carried by personnel.
- To prevent water reaching the generator and control box during operations, with its attendant dangers to operators and damage to equipment, the bilges of the boat must be kept dry by pumping, bailing or mopping as necessary.
- Where motor powered generators are used a suitable fire extinguisher should be carried.
- To minimise the risks of boat instability, and operators tripping, equipment must be securely stowed.
- Care must also be taken to avoid tipping or rocking the boat, which may cause operators to lose their balance.
- Lifejackets must be worn at all times.

Bibliography

- Anon. (2003). *Water Quality – Sampling of fish with electricity*. BS EN 14011:2003. British Standards Institute, London.

- Beaumont, W.R.C., Taylor, A.A.L., Lee, M.J. and Welton, J.S. (2002). Guidelines for Electric Fishing Best Practice. Environment Agency R&D Technical Report W2-054/TR. pp206. Pdf file downloadable from http://publications.environment-agency.gov.uk

- Beaumont, W.R.C., Peirson, G. and Lee, M.J. (2006). Factors affecting the characteristics and propagation of voltage gradient fields from electric fishing anodes. *Fisheries Management and Ecology*; **13**; 47-52.

- Cowx, I. G., Lamarque, P. (eds.) (1990). *Fishing with Electricity: Applications in Freshwater Fisheries Management*. Fishing News Books. Blackwell Scientific Publications Ltd. Oxford.

- Cowx, I. G. (ed.) (1990). *Developments in Electric Fishing.* Fishing News Books. Blackwell Scientific Publications Ltd. Oxford.

- Environment Agency (1998). *Electric Fishing Theory and Practice*.

- Environment Agency (2001). *Electric Fishing Code of Practice*. EAS/6100/4/02.

- European Inland Fisheries Advisory Commission: Working Party on Fish Monitoring in Fresh Waters. Draft: Information Note: Electric Fishing Best Practice. Pdf available from www.fao.org/fi/body/eifac/eifac.asp *Follow link from EIFAC homepage to "Information about the Working Group and documents relevant to Fish Monitoring".*

- Snyder, D.E. (2003). Electrofishing and its harmful effects on fish. USGS Information and Technology Report USGS/BRD/ITR—2003-0002. 149pp PDF file downloadable from www.fort.usgs.gov/products/publications/