HELLENIC CENTRE
FOR MARINE RESEARCH

INSTITUTE OF
MARINE BIOLOGICAL RESOURCES
AND INLAND WATERS

INLAND WATERS FISH MONITORING OPERATIONS MANUAL

ELECTROFISHING HEALTH AND SAFETY / HCMR RAPID FISH SAMPLING PROTOCOL

VERSION 1.0

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Contents

Introduction

1. The scope of this work

This is the first version of the official field operations manual for inland waters fish surveys produced at the Institute of Marine Biological Resources and Inland Waters (IMBRIW). This version the manual is designed to provide assistance to field workers in routine fish sampling, primarily employing electrofishing methods in streams and rivers. Electrofishing is the main sampling technique for Water Framework Directive (WFD) and for conservation-relevant fish sampling surveys in lotic freshwaters (e.g. Habitat Directive applications). This manual aims to guide and promote scientific electrofishing, focusing first on safety and providing an interpreted protocol for standardized ichthyological data collection.

2. Who this manual is addressed to

Scientific sampling of fish assemblages in inland waters is not commonplace in Greece or other Balkan or Eastern Mediterranean countries. Standardized and replicable techniques have rarely been applied by official research agencies. As policy-relevant conservation and management applications move forward, more organisations and individuals will probably be involved in inland waters fish surveys in the future. Such organisations and individuals may include: government research agencies, academic institutions, protected-area management bodies, environmental NGOs and free-lance contractors, technicians and/or scientists working in the private sector. Students and volunteering members of the public may also accompany field survey teams. With increased policy obligations for fish-based bioassessment in both river management and nature conservation, scientifically sound sampling of inland waters fishes should expand as it has the rest of Europe.

Field fish surveys involve health and safety risks and require specialised training, standardization of sampling and informed collection methods, technical effectiveness, and special consideration for biodiversity conservation. Producing safety guidelines will help those involved in fish sampling to greatly reduce health hazards and environmental risks during sampling. Furthermore, this guidance aims to promote methods for standardising fish sampling, in order to make surveys repeatable and data collection comparable for monitoring applications.

3. How to use this manual

Version 1 of this manual is provided in a provisional draft form, for initial guidance and peer review.

This manual includes the following: a) electrofishing health and safety guidance; b) electrofishing guidance on theoretical and practical aspects; and c) guidance on using the HCMR's rapid fish sampling protocols.

This document should assist in the following:

- Briefing all members of field work teams conducting fish sampling;
- Informing all interested parties and stakeholders who are directly or indirectly involved in inland waters fish sampling, surveying and monitoring;
- Guiding good-practice, conservation awareness and standardisation in fish sampling techniques;
- Providing a framework for specialised training seminars.

The issue of best-practice and standardization in electrofishing operations in Greece and the adjacent regions is in an early stage of development. This manual is a document for guidance and adaptive development. In terms of field safety issues, by adopting guidelines it should not be necessary for institutions to increase bureaucracy prior to routine electrofishing surveys. Obviously many instances of field work can be demonstrably assessed as low risk. Field sampling can be assessed as a low risk activity if careful planning and consideration for safety issues are judiciously applied. Furthermore, scientists must be careful not to impact the ecosystems and fish populations they sample. And again, this requires increased awareness, understanding of the specific problems and training.

4. Future steps for improvement of this operations manual

Future versions of the manual will include amendments and revisions. Finally, the work will also be translated in the Greek language. Please check for revised versions available at the institute's website: http://imbriw.hcmr.gr/en/.

Please direct comments about this version to the co-editor at: zogaris@hcmr.gr.

PART 1
HEALTH AND SAFETY

1. Potential dangers

Working near or in water bodies is associated with potential health and safety risks. Training and following common sense safety procedures are crucial in minimising the probability of accidents. Because accidents are rare in inland waters fish sampling, it is easy to become complacent and ignore some dangers.

However, we should remember that accidents may easily occur in field work. Field experience shows that potentially dangerous aspects of field work include the following risk categories:

1) Travel and vehicle related accidents to and from field sampling sites.
2) Accidents during sampling, involving trauma particularly from slips and falls and the extremely unlikely event of drowning.
3) Accidents concerning equipment failure or misuse.
4) Accidents or health risks due to extreme weather conditions and river conditions (extreme weather events, flooding, artificial river flood-flow patterns etc).
5) Other unlikely threats related to disease infection and conflicts with animals and people.

A simple review of safety issues in field conditions can be found in: http://arssymposium.absa.org/pdf/V-VandeWoude.pdf

Greece and the adjacent Balkan and Eastern Mediterranean regions host conditions that are very similar to other southern European countries and usually pose relatively low risk for field work in streams, river corridors and wetlands. An awareness of any risks is important to avoiding dangerous situations. The following list summarizes potential dangers (not presented in order of importance/likelihood of occurrence):

- *Driving safety*: vehicle-related injury is probably the most common and serious threat during sampling trips, either when travelling or near sampling sites. In Greece, most rural roads are poorly maintained and sometimes poorly signed. Additionally, access to/from sampling sites situated in remote and inaccessible areas where driving and manoeuvring a vehicle is demanding, increases the risk of accidents.
- *In-stream accidents*: Falls from slipping are the most frequent hazards in upland streams and these can be very serious. Drowning is a possible hazard even in rather shallow fast-flowing waters and in lakes. Personnel must be well trained and cautious; the ability to wade safely in a fast-flowing stream or river is gained by practice. Still, it is highly recommended not to wade when one is not sure about personnel safety. Life-vests should be worn where deeper water and/or water flows may pose a risk. Scheduling sampling at another time of the year, usually far at the end of the dry season, or searching for a more appropriate sampling sites nearby, usually is the best solution to this risk.

- *Electrofishing working accidents*: These rarely occur if the team is experience and trained. Dangers of electrocution are obviously priority (see below). But simple mistakes can cause problems. When netting fish for example, care needs to be taken not to hit other workers with the net poles. Grievous injury can be caused in this manner, especially if the end of a net pole is pushed into the face of another member. Workers must not work if particularly tiried, ill or under severe time constraints. It is alright to leave a site "half-finished" if time and safety issues interfere.
- *Weather conditions – flood risk etc*: It goes without saying that weather conditions must be monitored, especially the issue of temperature extremes and flood risk. Heat-wave conditions during summer or storms can cause dangerous situations. Proper care must be taken in such cases; for summer work: hats, long sleeve shirts and a drinkable freshwater stock are necessary. Observing storm or precipitation levels is important to avoid storm-conditions and torrential flash-floods. Torrential flash flooding have claimed several lives even in small river basins in Greece. Flood hydro-peaking from hydro-electric installations are also a common artificial flooding problem. These hydro-peaking flows may also be affected or increased by adverse weather conditions. Lastly, in there is no reason to electrofish in the rain; the threat of lightning is an obvious danger.
- *Shepherd guard dogs*: Especially around sheep-folds or livestock dogs may attack workers. Rabies has recently re-surfaced in Greece and special care must be taken of stray dogs everywhere in the country. Particular behaviour around dogs can help avoid any such incident of attack. Keeping in a group and wielding a stick are important effective behaviours in a dog-human confrontation (never run!).
- *Shooting/hunting*: Recreational hunting is widespread; hunters often stalk for wildlife near river sampling sites (especially in riparian areas). This may be potentially dangerous during autumn, especially during early morning hours or in poor visibility. In such cases wearing bright clothes and talking loud when moving through vegetation, so that everyone is aware of human presence, is highly advisable.
- *Other animal or wildlife risks*: Mosquitoes and ticks are widespread in Greece and pose specific serious threats (see below). Bees and wasp bites are common and particularly dangerous in case of allergic shock. The team leader must be prepared to react to such an event (first-aid, evacuation procedure). Snakes and spiders are much less of a danger; the risk is certainly minimal and exaggerated, but common sense is required. In Greece, only the viper species (Viperidae) are venomous to humans though non-aggressive, they do not pose a serious threat if simple precautions are taken. In the extremely unlikely event of a viper bite, one must seek medical assistance and keep calm. Emergency phone numbers and planned routes to the nearest medical facilities should always be at hand. It should be said that there are very few other animals that will bother humans (especially humans in a group). The extremely unlikely encounter with Brown Bear in a sensitive situation (with cub or with food-carcass) is a possibility in riparian zones, particularly in Northern Greece. Personnel should be informed about the best way to behave in areas with relatively high bear densities (as indicated by tracks and scat).

- *Military minefields/ Military sensitive issues*: Minefields, in some specific cases are poorly marked; they exist near the Greek-Albanian and the Greek-Turkish borders. When this is the case, do not stray away from main rural roads. Also, it goes without saying that any seemingly “suspicious” behaviour near military sites must be avoided.
- *Authority controls*: During investigative sampling, especially near international borders, authority controls, including police and military controls are common. Keep personnel relaxed, always display official paperwork proving your scientific expedition, and cooperate with relative authorities. In protected areas it is always necessary to have previously informed management bodies and/or other relevant authorities prior to sampling.
- *Assault by humans*: Extremely rare and unlikely in Greece. Perhaps an increased potential for any kind of assault may exist near larger cities or small shanties and Roma camps. River corridors are also sometimes used for illegal cannabis cultivation and surveys could create suspicion. During investigative sampling, local advice about any such problems should be sought.

2. Special Considerations

Protection from Mosquitoes

For over 40 years Greece enjoyed immunity from mosquito-borne diseases, and people are not especially careful of mosquito bites. During the last few years *Malaria* has resurfaced and localized incidents of *West Nile Virus* have occurred. Important points to consider for protecting the team members from mosquito bites include:

- Using mosquito repellent. Apply insect repellent containing DEET (N,N-diethyl-meta-toluamide) or other/similar types .
- Whenever possible, wearing long-sleeved clothes, socks and long pants.
- Wearing clothing that helps you blend in with the background. Mosquitoes hone in on colour contrast and movement.
- Treating your clothes with permethrin repellents. Do not use permethrins on your skin!
- Avoiding perfumes, colognes, fragrant hair sprays, lotions and soaps which attract mosquitoes.
- Reduce your risk of exposure by not working in prime mosquito habitat during mosquito activity peak feeding hours (dusk and at dawn).

Weil’s disease and Lyme disease

At the field, crew must be aware of the hazard of Weil’s disease (*Leptospyrosis*) and Lyme Disease (*Lyme borreliosis*).

Weil’s disease is associated with contact with contaminated river and canal waters. To minimise the risk:

1. Properly clean and cover with waterproof plaster any wound such as scratches and cuts

2. Avoid touching your mouth, eyes and nose
3. Wash your hands before eating and drinking
4. Clean clothing and equipment that has come in contact with dirty water before the next use

Lyme disease is a tick-borne disease. To minimise the risk:

1. Wear appropriate clothing to cover skin. Avoid clothing such as short trousers that leave legs uncovered.
2. Check your body for ticks, during and after the survey.
3. If a tick is found remove it as quick as possible.
4. Seek medical attention.

3. Field work safety

Basic health and safety guidelines/considerations for all types of field surveys near and in inland water bodies, particularly river conditions, include the following:

- In the field the team leader is responsible for following safety procedures. If any member of the team should identify a hazardous situation they are to immediately notify the team leader. Hazardous situations or any accidents must also be recorded in the field protocol (under Miscellaneous information) in order to inform future sampling.
- Basic first aid training is essential for all the team members. Special focus must be given on administrating assistance in cases of electrocution (when electrofishing), drowning, falls, cuts, sun stroke, choking, minor and major injuries.
- A first aid kit must always be available and the route to the nearest medical facilities should always be planned. Contact numbers for police, ambulance and fire department should always be available.
- As the most common hazards of field surveys are cuts, slips, water-borne disease infection, heat exhaustion, hypothermia and drowning a trained response to these problems should be routine. Appropriate field clothing is required to minimize those risks. Skin coverage is sought to avoid cuts and scrapes, ticks, insect and snake bites and prolonged sun exposure.
- In low water/ambient temperatures warm clothes should be worn under the protective equipment to prevent hypothermia. In hot temperatures care should be taken in order to avoid heat exhaustion and sunstrokes. Workers must not work if they are ill (since being sick/unwell increases risk of injury or other complications).
- Rubber anti-slip thigh boots and chest waders should be used according to the depth of the river. Life jackets are required in deeper wading conditions and must always be worn in boat surveys.
- Presence of glass or sharp metallic pieces is frequent in river beds. All personnel should be cautious when wading especially when river bed visibility is low. In case of rusty metals further caution is required, especially if a team member is not immunised.

- In case of contact with contaminated water/water suspected for pollution, exposed area should be thoroughly cleaned and disinfected as soon as possible. Disinfectants must always accompany a field survey tool-kit. Surgical or washing gloves should be worn in polluted waters.
- Sampling at sites with high water flows and/or current velocities should be avoided. Special consideration is required at sites where point discharges substantially increase the water volume. This holds particularly true when sampling downstream of dams, where water may suddenly be released from the spillways.
- The survey should be carried out only when local conditions allow for safe sampling. In the case of extreme weather (i.e. heavy rain, thunderstorm, and lightning), extreme flow conditions, unstable banks and/or substratum, dense vegetation, accessibility issues and nearby activities that could interfere with the sampling process, sampling should not be attempted. Safety checklists, filled out prior to the sampling at each site, are recommended.

4. Electrofishing field safety

The combination of electricity and water is potentially hazardous for the operators. In addition to the risks associated with all types of river field surveys, the possibility of an electrical shock, temporary incapacitation and electrical burns needs to be taken into account. Those risks are greatly minimised if the appropriate working procedures are followed. In this section we will go over the main safety concerns and the health and safety guidelines that everyone should be familiar with before using electrofishing equipment.

Staff should be in good health condition and fit for the task, to participate in an electrofishing survey. An effective means of keeping fit is gym/physical training before an electrofishing expedition.

People suffering from known heart conditions should not participate in electrofishing surveys. Team members should be trained in cardiopulmonary resuscitation (CPR). A guide on CPR should be handed out to all members of the team.

If new equipment is used trained members need to revisit training. For safety reasons a minimum of three people should carry out the surveys.

Protective equipment

Protective gear made of non-conducting materials, should be worn by all members of the staff.

- Thigh or chest waders made from non-conducting material, frequently inspected for leakage. If leakage occurs, the staff member must be removed from the water.

- Protective rubber gloves covering hands and forearms, frequently inspected for leakage. Only personnel wearing protective gloves are to come into contact with the water while the electrical current is on.

- Life jackets are recommended in depths greater than knee level, unless the staff member is wearing a dry suit.

- Clothing should not have any metallic components that may influence the electrical field or parts that are sticking out and may become entangled with cables or nets.

Electrical health & safety summary

The following rules apply:

- do not allow unprotected parts of the body to come into contact with the water when electrofishing equipment is operating;
- only those parts of the equipment (electrofisher’s anode, dip nets, buckets) that are covered by non-conducting material should be touched with bare hands. Under no circumstances should anyone touch the water during operation unless the electrofishing gear is verified to be switched off or they are wearing rubber gloves:
- only the operator in charge of the hand held electrode (HHE) can remove debris from the electrode by hand and only after being sure that the fishing circuit is de-energised with all stop buttons in the locked off position;

- do not leave electrodes unattended when they are connected to a live power source;
- under no circumstances, allow the electrode head to leave the water before the safety control circuit switch is released;
- avoid simultaneous use of more than one set of electrofishing equipment at any one site. This kind of sampling is rarely capable of being standardized (or repeatable) so it is therefore inappropriate for monitoring routines as well.
- all personnel must be fully familiar with the operation of the equipment before being allowed to use it for electrofishing;
- avoid to make any electrical connections or refuel the generator (Direct Current engine) the system should always be turned off and allowed to cool.
- operation manuals for each type of fishing gear must be available to those involved with its use;

Some of the above are summerized in Table 1 (adapted from Goodchild 1991, Meador et al., 1993).

Table 1. Health and safety do's and don'ts

Do's	Don'ts
Keep hands out of the water during the survey	Operate electrofishing equipment alone
Leave the water immediately in the event of a leakage	Fish under inclement weather conditions (moderate to heavy rain, lightning, thunderstorm)
Make electrical connections/disconnections when the system is switched off.	Fish when the crew is extremely tired
Refuel generators when the system is off and surfaces have cooled down.	Fish when people or animals are near/in the water. Fish near electricity poles or other areas were electricity may enter water
Review training and standardization aspects of electrofishing operation before a campaign.	Fish near hydro-peaking areas down-stream of discharge channels were frequent flood pulses occur
Prepare a first aid kit and refresh it often.	
Rest often during electfrofishing.	
Be alert and conscious.	

Training

In order to promote health and safety and best-practice procedures in electrofishing workers should be trained and professionally certified. Before going out on the field, proper training from an experienced electrofishing operator-trainer is required in:

- health and safety guidelines,
- principles of electrofishing
- use of electrofishing equipment
- first aid training

This manual introduces several aspects of the above but it is not a substitute to professional training.

The best precaution against outdoor dangers or risks in field work is professional training. Personnel must undergo training before participating in a field survey. Boat safety training is an absolute requirement for boat surveys. There are many forms of formal and informal training structures (Fig. 1).

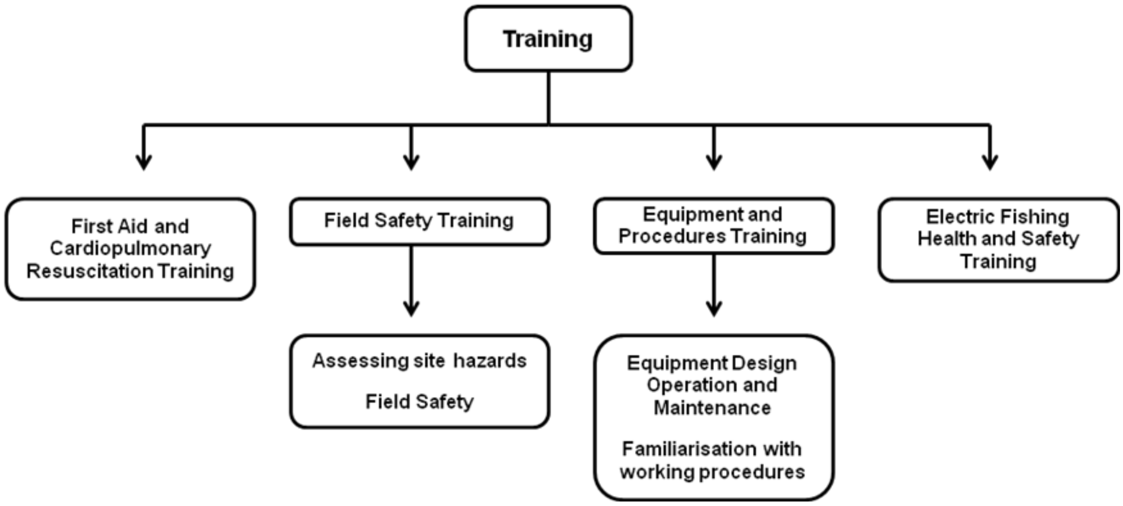


Fig. 1. Conceptual diagram of the basic training programme (Source: W.R.C. Beaumont).

PART 2

ELECTROFISHING GUIDE

1. Introduction

Brief description

The term electrofishing (or electric fishing) is given to the method of applying an electric field to water in order to incapacitate fish, thus making them easier to catch. When set-up and used properly the method should cause no lasting harm to the fish. However, when incorrectly set-up or used by inexperienced operators harm can be done to both fish and operators. For this reason it is important that operators are suitably trained.

History and uses

Isham Baggs patented the method in 1863 as ‘Paralysing fish, birds etc.’ but interest in the method really began in the 1930’s as electronics and generator technology improved. The technique has many advantages over other methods available to fishery workers for capturing fish and it is presently the main-stay method for sampling fish in relatively shallow freshwaters; being used for tasks as wide-ranging as population estimation, broodstock removal and pest species removal.

The effectiveness of fishing is affected by several factors, thus appropriate equipment set up, in order to sample effectively and without getting fish harmed is a challenge. Knowledge of baseline theory and electrical current attributes is essential. Within the electrofishing user community the lack of adequate knowledge, regarding the ‘correct’ settings has resulted in electrofishing being regarded as an art rather than a science (Kolz 1989). This lack of fundamental knowledge is encapsulated by the common practice of referring to the pulse box as ‘the magic box’. Whilst it is possible to capture fish without knowing how the technique works, knowledge of the fundamentals will enhance catch efficiency and help reduce fish injury. Knowing basic electrical principles will also allow operators to effectively calibrate equipment, in order to produce similar/proportional fish capture probabilities and thus improve standardisation among sampling in different locations or time periods.

2. Electrofishing Theory

Basic electrical terms

With reference to electrofishing, descriptions of electricity can be split into five principle components (Beaumont *et al.* 2002).

1. Voltage
2. Current
3. Resistance
4. Power

Voltage

Voltage can be described as the potential or electromotive force of the electricity and is measured in Volts (V).

In electrofishing, when the electricity is applied into water (via the electrodes) it spreads around the electrodes creating a voltage gradient or field of decreasing intensity with increasing distance from the electrodes.

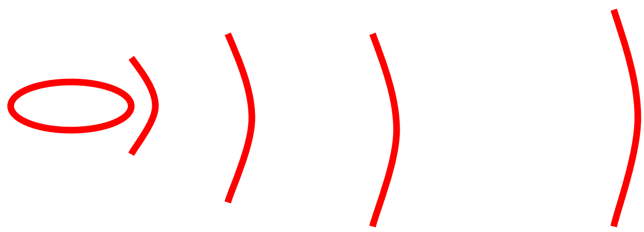


Fig. 2. Schematic drawing of voltage gradient around an electrode (voltage between the lines is constant).

The circuit voltage that needs to be applied to create a voltage gradient at the electrodes that will attract and immobilise fish will vary according to:

- the output type used (Direct Current or Pulsed Direct Current)
- ambient water conductivity
- the anode size used
- the cathode size used (and the anode/cathode electrical resistance ratio).
- size of effective capture field required.

Simply increasing the voltage alone will lead to high power consumption and it will have a stronger, possibly harmful effect on fish. High voltages are related to vertebrae injuries and prolongation of the recovery time.

It should be noted that it is the current or power density that actually affects the fish and that voltage is just one of the ways we can alter that value (the other being with pulse width). Ideally, voltage should be limited to what is required in order to create a current gradient sufficient to immobilize fish within it's' field, but from which they recover the moment they are removed from it. The ‘correct’ voltage value will depend on the diameter of the anode (larger anodes giving a lower but wider gradient) and the conductivity of the water (low conductivity water demands higher gradients).

Voltage can be described and measured in a number of ways.

Peak voltage (**V_{pk}**) is the maximum voltage attained i.e. zero to maximum value.
Peak-to-peak (**V_{pp}**) is the minimum to maximum values; it is used for voltages that have a negative component to them, e.g. AC.
Root-mean-square voltage (**V_{rms}**) is the equivalent steady dc voltage that would transfer the same power into the water. In simple terms it can be likened to average voltage over time.

For steady dc both Vpk and Vrms methods will give the same reading; and Vpp equals zero. For pulsed voltages, however, Vpk and Vrms will give a different answer. Peak voltage will measure the maximum voltage attained by the pulse, while the rms value will be lower. Most standard voltmeters can measure either steady dc voltage or ac voltage; if used on pdc waveforms they will give Vrms values. Only specialised Digital Volt Meters (DVM) and oscilloscopes can measure the peak (and peak-to-peak) voltage of pulsed currents.

Current

Electrical current is the quantity of charge moving through a circuit per unit of time i.e. the coulombs per second; it is measured in Amperes (Amps). It dissipates around the electrodes and its density decreases with increasing distance. The shape of the electric current field is determined by the shape of the electrode.

Current density (J) is the current per unit area of cross-section; it is measured in Amps per square metre (A/m^2) but in electrofishing in A/cm^2 more commonly. An approximate value can be calculated from:

J = Voltage gradient X water conductivity.

High current densities may be as harmful for fish as high voltage. Many consider that current density is the most significant factor in determining a fish’s reaction to an electrical field. By integrating a measure of water conductivity into the parameter it also enables standardisation of outputs in differing conductivity water.

There are two principal waveforms of electrical current, alternating (bipolar) current (AC) and direct (unipolar) current (DC). Direct current is subdivided into continuous (smooth) direct current and pulsed direct current (PDC).

Alternating Current

The electrodes are not permanently charged and the current flows in one direction until a maximum is reached and then the polarity is reversed. This reverse is repeated many times for every second (usually 60).

AC has many advantages. It is easily generated even when using small generators, fish response is elicited with low voltage and there is low variability due to site physical characteristics. However, it does not have a strong attraction potential (especially when fish are seeking cover in vegetation or substratum features) (Scottish Fisheries Co-ordination Centre, 2007). Moreover, fish tetanus and mortality rates are significantly higher than DC (Beaumont *et al.* 2002). It is also considered to be less safe to operate. For all the above AC must not be used for electrofishing.

Continuous Direct Current (DC)

Direct current only flows in one direction; from the cathode (negatively charged electrode) to the anode (positively charged electrode). The flow of the current between the electrodes is continuous.

DC creates a smooth electrical field, thus it is less likely to cause tetanus to fish, compared to AC or PDC. With the exception of high DC currents which might lead to tetanus, fish usually experiences a state of non harmfull narcosis. This inhibits movement but does not cause muscle spasms. If not in tetanus, fish will usually recover instantly when the current is switched off. While DC is more efficient in attracting fish, immobilisation is harder to achieve.

Site-specific physio-chemical factors, such as streambed conductivity, greatly affect smooth DC waveforms. Voltage gradients needed to attract fish are much higher, compared to PDC. Additionally, continuous nature of the current means that the waveform has a higher power demand than for other waveform types. This may be particularly problematic when using backpack equipment or small generators, especially in high conductivities where the power required to maintain current is higher. According to the draft guidelines of the European Inland Fisheries Advisory Commission (EIFAC), in respect to power demand, DC should be used in water conductivities up to 150 μS/cm for backpack gear and up to 500 μS.cm-1 for generators; although the latter conductivity value would still require quite large generators to provide sufficient power.

Fish reaction in DC electrical field depends mainly on the proximity to the anode and the direction in which the fish is swimming. Table 2 shows the phases of reaction that fish go through when they encounter an electrical field of DC waveform, facing towards and away from the anode.

Table 2. Fish reaction in DC waveforms
[adapted from Scottish Fisheries Co-Ordination Centre, 2007: Beaumont et al. 2002]

<table>
<tr>
<td rowspan="2">Fish facing towards the anode</td>
<td rowspan="2">Indifference:
The current flow is not sufficient to stimulate the nervous system – No effect

Galvanotaxis:
“Voluntary” swimming: Introduction to the electrical current stimulates the central nervous system and the fish starts swimming towards the anode.

Galvanonarcosis:
As the fish comes closer to the anode, the ability to swim is inhibited, it’s muscles remain relaxed

Pseudo-forced swimming:
Even closer to the anode, the electrical field stimulates the muscles causing swimming towards the anode again

Tetanus:
In high DC currents, the muscles may spasm causing impaired breathing and vertebrae injuries.</td>
<td>Spasmodic swimming:
The current stimulates the fish motor nerves, the fish may try to escape to the indifference zone.

Half turn to the anode:
If the anode is brought closer to the fish after the previous phase, stimulation of the nervous system may cause the fish to move so as to start facing the anode. After these phases the fish reacts the same way as if it was originally facing the anode.

Tetanus:
Caution is needed since the fish may already be too close to the anode by the time it has completed its’ turn.</td>
<td>Fish facing away from the anode</td>
</tr>
<tr>
<td>Alignment - Anodic curvature:
The fish is influenced by the field across its length and it may be required to move the anode closer to it to induce a reaction. The nerves on the side facing the anode are stimulated causing the fish to “bend” towards the anode. Afterwards the fish reacts the same way as if it was originally facing the anode.</td>
<td>Fish facing sideways the anode</td>
</tr>
</table>

Pulsed Direct Current (PDC)

Instead of a continuous current (DC) the current is pulsed (PDC). PDC is usually a unidirectional type of current i.e. no negative component. Physico-chemical variability does not affect pulsed DC to the same extend as direct current. Attraction is achieved using lower voltage gradients and this together with the current being turned on intermittently results in a significantly lower power demand (often only 25% of that for DC).

The attraction zone of pulsed DC is smaller than for continuous DC. PDC is less efficient than DC in drawing fish from cover. Instead of stimulating the fish’s nervous system, attraction is achieved by direct impact on the muscles. Current levels needed to induce attraction and narcosis/tetanus are lower than for DC, leading to a greater risk of damage to the fish. Table 3 summarises the effect of PDC on fish. In Table 4 a comparison between the two methods can be found.

Table 3. Fish reaction in PDC waveforms
[Adapted from Scottish Fisheries Co-Ordination Centre, 2007)

<table>
<tr><td rowspan="2">Fish facing towards the anode</td><td rowspan="2">Indifference:
The current flow is not sufficient to stimulate the nervous system – No effect

Electrotaxis:
The fish is drawn to the anode due to muscles' contraction with each pulse instead of nerves' stimulation.

Tetanus/ Narcosis:
Near the anode the fish becomes immobilized (like galvanonarcosis in DC but at a lower voltage gradient). If the fish is not rapidly removed from the electrical field, tetanus may occur.</td><td>In general fish react in a similar way as in DC currents</td><td>Fish facing away from the anode</td></tr>
<tr><td>In general fish react in a similar way as in DC currents</td><td>Fish facing sideways the anode</td></tr>
</table>

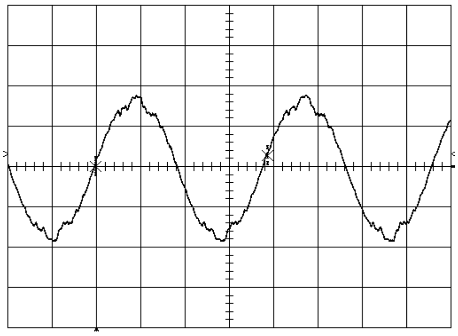
Table 4. Comparison between DC and PDC waveforms [adapted from EIFAC)

Direct Current		Pulsed Direct Current	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
Larger attraction zone	High power demand – Only effective in low conductivities	Lower power consumption – Suitable for all conductivities	Narrower attraction zone compared to DC
Better welfare properties	Affected by physic-chemical factors	More consistent performance between sites	Increased tetanus risk
Reduced tetanus risk	Limited narcosis capability	Efficient in immobilizing fish	

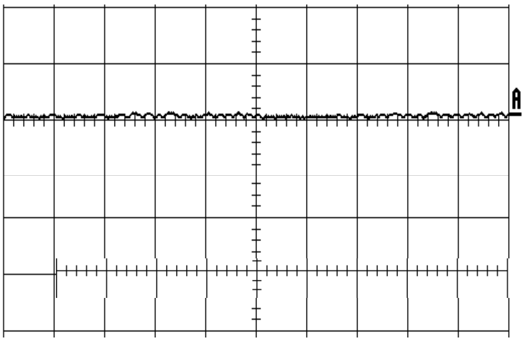
Pulse Shape

The shape of the pulses used in PDC fishing may take many forms. Fig. 3 shows the most common together with the shape of an AC and smooth DC waveform for comparison.

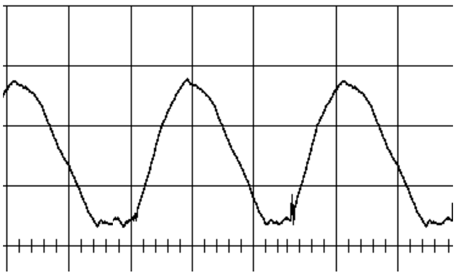
Fig. 3 Waveforms for comparison



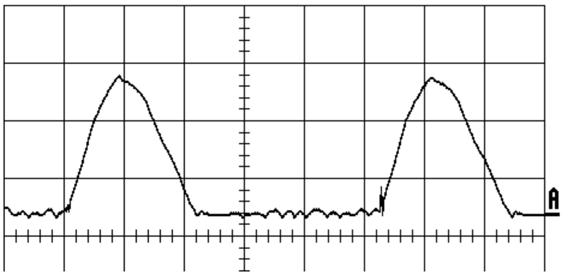
Alternating Current (AC)



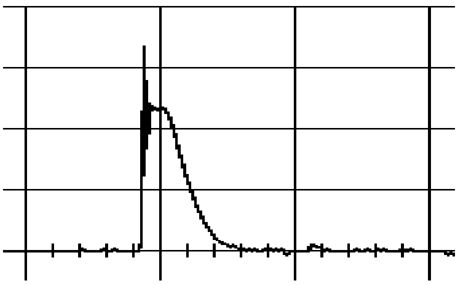
Direct Current (DC)



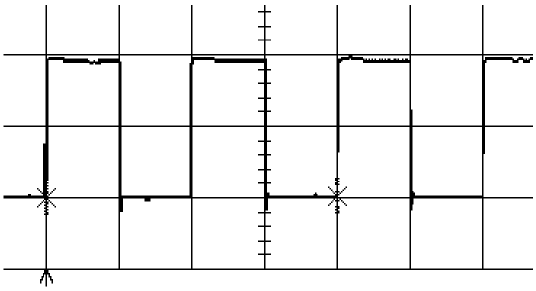
PDC – Full-wave rectified



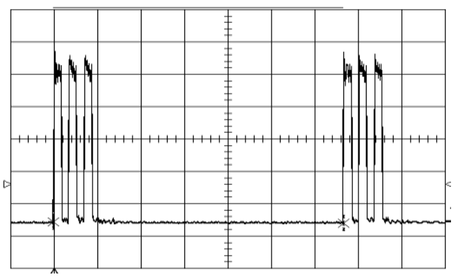
PDC – Half-wave rectified



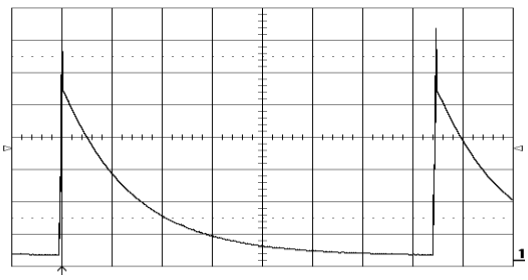
PDC – ¼ sine wave (note spike on leading edge)



PDC - Square wave



PDC – Gated Burst



PDC – Exponential pulse

Either converting the negative component of an AC waveform to positive, or removing it, will create PDC full or half wave rectified waveforms. For a standard 50 Hz generator this gives either 100Hz PDC (full-wave rectification) or 50 Hz PDC (half-wave rectification).

Research indicated that a steep leading edge to the waveform provided the maximum physiological effect on the fish. This waveform is achieved by removing the leading part of a rectified waveform. Further research however indicated that the efficiency of this ¼ sine wave waveform was due to its tetanising power and thus such a waveform was the most damaging of the PDC waveforms. Due to these findings ¼ sine waveforms have been banned in some states in the USA.

Most of the newer designs of pulse box use square waveforms. This waveform combines the advantage of good physiological effect, with the ability to control and replicate pulse duration and frequency, thus allowing standardised power to be used.

Exponential pulse or capacitance discharge waveforms are produced by charging a capacitor, which is then discharged through the electrodes. Because this discharge is of short duration this pattern has the advantage that high voltages are available for fishing, whilst, because pulse width is small, loading on the power source is small (i.e. rms voltage is low). Some concerns have been raised about injury rates but Sharber & Carothers (1988) found that injury rates for exponential pulse were no worse than for square waveforms.

Gated burst waveforms consist of a series of high frequency pulses repeated in a lower frequency pattern. Some advantages may be obtained from this waveform in terms of reducing fish injury and for conserving power (30% of square wave) when it is limited e.g. very conductive water or when using battery-powered equipment.

Modern electrofishing control boxes also have the facility to produce a variety of non-standard waveforms. However, the principles behind these (e.g. decreasing pulse interval, high to low frequency variation) are probably not valid in real-life situations and, until evidence shows some benefit from their use, they are best avoided.

Pulse Frequency

Pulse frequency is the number of pulses generated per second; it is measured in Hertz (Hz). High frequencies (above 100 Hz) have been shown to injure fish more than lower frequencies, so fishing should always be carried out at the lowest frequency possible. Different species of fish have also been shown to react more to some frequencies than others. For example, frequencies of 40-60 Hz have been found to be very effective for attracting and immobilizing salmonid species whereas 10 – 20 Hz has been found to give good results for eels and lampreys. However, if electrofishing is applied for a wide variety of species frequencies around 30 – 60 Hz should give well capture rates, with minimal injury.

Pulse Width / Duty Cycle

The duration of a pulse is called the pulse width. It can be expressed in milliseconds (the duration, measured in ms, that current flows in one pulse) or duty cycle (the percentage time of the electrical cycle during which the electricity flows). Altering the pulse width will affect the overall amount of electrical energy imparted into the fish and will also affect the power demand of the equipment. A 25% duty cycle will use half the power that a 50% duty cycle would (and ¼ the amount of using smooth DC). It does not influence the attraction potential of the current, like frequency does, but increasing the duration of pulses may increase the immobilization efficiency. Duty cycles of between 10% and 50% have also been shown to have the largest difference between the power needed to immobilize the fish and to tetanise them, thus increasing the safety factor for the fish. This is particularly so in high conductivity water where increasing the pulse width (up to a maximum of 50% duty cycle) can help immobilize fish. Values above 50% duty cycle have been found to be ineffective in improving immobilization. Values below 10% duty cycle have been found to need higher voltages to remain effective. However, Beaumont *et al.* (2000) found catch efficiency of a 3% duty cycle was similar to a 36% duty cycle comparison, but had much higher catch per unit power.

Resistance and Conductivity

The electrical resistance of a substance is its opposition to the passage of an electric current through it. It's measured in Ohms (Ω). The inverse metric is electrical conductance, meaning the ease with which an electric current passes through a substance, measured in Siemens (S).

Electrical resistivity is a measure of how strongly a specific material resists the flow of an electric current. Low resistivit©y of a substance indicates that it readily allows the movement of electric charge. The unit to measure electrical resistivity is the ohm.metre (Ω.m). Electrical conductivity is the reciprocal of resistivity (1/Ω) and measures a material's ability to conduct an electric current. It is the more common term used when describing the electrical properties of water, measured in siemens per metre (S.m−1) although when used to describe the conductivity of water it is more often expressed as microsiemens per centimetre (µS.cm-1).

The conductivity (resistivity) of water will vary with temperature. For this reason conductivity values are usually temperature corrected to what the value would be at 25º Celcius, so called 'Specific Conductivity'. When electrofishing, however, we need to know conductivity at the temperature in which we are fishing; 'Ambient Conductivity'. Most low priced conductivity meters measure the former and either more expensive units should be used to measure the latter or the value can be corrected if the water temperature is known. The computer program 'ElectroCalc' will also carry out this calculation (see Section B.1).

River and stream conductivity will vary with the water chemistry and the amount of ions in the water. Streams running off igneous (e.g. granite) catchments will have a low ionic content and will have low conductivity. Those running off limestone or chalk will have a high ionic content and high conductivity.

In electrofishing, the resistance of the fishing circuit is the sum of the water resistivity and the resistance of the electrodes in contact with the water. The electrode resistance is determined by their separation, size and geometric shape; with large diameter anodes having a lower resistance than smaller ones. This combination of water and electrode resistance is termed the ‘Equivalent resistance’ of the electrodes. As both power and current are functions of electrical resistance, the equivalent resistance (together with the circuit voltage) will determine these parameters.

For example;
Electrical current = volts ÷ resistance
So if fishing in a low conductivity (high resistivity) 100µS.cm-1 (163Ω) stream and the circuit voltage is 200v, then current will be 200/163 = 1.2Amps.

However, if fishing a high conductivity (low resistivity) 800µS.cm-1 (20Ω) stream and the circuit voltage is 200v, then current will be 200/20 = 10Amps.

In general, electrofishing equipment can be usually operated within a conductivity range of 20 – 3000 µS.cm-1.

The ratio of the electrical resistance between the anode and cathode has a critical effect on the voltage that is actually produced at the anode. The principle behind this is called ‘Kirchoff’s Law’ and states that the voltage across two resistors in a circuit is proportional to the resistance between them. If both have the same resistance then the anode voltage is half the circuit voltage. However, anode and cathode are totally different in design and therefore resistance is not equal. Typically a 300mm ring anode (measured in 350µS.cm-1 water) will have a resistance of 33Ω whereas a 3m copper braid cathode will have (also in 350µS.cm-1 water) a resistance of 20Ω. This would give (for a 200V circuit voltage) 124 V at the anode (and 76V at the cathode). This is why it is preferable to have a high surface area (low resistance) cathode so that a greater proportion of the available power can be used at the anode. It is also why when if an additional anode is added to a fishing set-up, twin cathodes also need to be used in order to keep the anode voltage constant.

Power

Power can be defined as ‘energy per unit time’. For DC and PDC waveforms it can be calculated as:

Power (Watts) = $\text{Volts}^2 \div$ Resistance

Consequently, when fishing in low conductivity waters (high resistivity) less power will be needed to keep the electrical field of fishing equipment live. Conversely, in high conductivity waters more power will be needed (i.e. larger generators or faster battery depletion). In high conductivity water this power demand is often the factor that limits the ability to use electrofishing as a sampling method. For example if fishing 200V DC in 3000µS.cm-1 water, then a 4 kVA generator would be needed. Using smaller electrodes would reduce power slightly but might also result in high field gradients and damage of fish. Alternatively, PDC, at low duty cycles or using gated burst waveforms, can be used to reduce power demand of the equipment.

If using an AC generator to power the equipment a ‘Power Factor (PF)’ needs to be added to the calculation above due to inefficiencies on the conversion of AC to PDC. This PF can be estimated at 1.6 times the calculation above. Once added, the power should also be described as Volt.Amps (VA) rather than in Watts and high values in units of one thousand i.e. kiloVA (kVA).

Power transfer theory

As mentioned in the section on voltage, it is the power density (D) in the water that affects the fish.

This can be calculated from:

D (Watts.cm^3) = Water Conductivity x Voltage Gradient^2

Power Transfer Theory (PTT) states that when the water and fish conductivity are the same then maximum power can be transferred into the fish. When they differ more power will be needed to transfer the same energy into the fish, in order to achieve immobilisation. For more detail of how this affects electrofishing in different conductivity waters see below (under “fish conductivity”).

3. Other basic concepts and factors influencing electrofishing effectiveness.

Whilst knowledge of the above electric settings is the key to successful electrofishing, in reality a variety of factors influence the effectiveness of the method. These parameters include the following list.

Anode design

In electrofishing, anode shape determines the shape of the electric field, thus affecting the efficiency of attraction and immobilisation effect. This in turn affects the fish response and welfare. It is argued that the most effective anode shape is the ring or torus (Beaumont et al., 2002; Scottish Fisheries Coordination Centre, 2007). It spreads a uniform, donut shaped, electrical current in every direction. Its' current density gradually decreases with distance from the center of the ring. Any anode that has 'corners' or 'points' on it will project a more intense field from those points, leading to a risk of fish injury. For this reason flat plate, square, triangular and rhombus shaped anodes are not recommended. Metal mesh attached to the anode will modify the voltage gradient, reducing field density. However, if a mesh is fitted on the electrode it should never be used as a net to lift fish from water, due to the high field intensities that will still occur at the metal surface. Anodes used for netting fish should always be fitted with a non conducting net.

Electrode size influences greatly the size of the electrical field in the water and different voltages will be needed with different anode sizes. In general, it is believed that the field should be as large as the circumstances allow in order to maximize attraction zone but minimize tetanus zone. However, in small streams large anodes may not fit or become handy. In any case, an anode diameter of 300 – 400mm is strongly recommended for any electrofishing procedure, unless stream size is very small (Beaumont et al., 2002). Getting sufficient power to maintain the electrical field from a large anode may be difficult, especially in high conductivity water (where equivalent resistance will be lower) or when using a small power supply (i.e. backpack equipment). Considering all the above, it is advisable to carry around different sized anodes.

Power demand of the anode-cathode set-up may be calculated theoretically based on electrode resistances or empirically by field measurements. Theoretical values can also be assessed by using ElectroCalc program:
http://www.gwct.org.uk/education__advice/courses__training_days/courses_by_type/fisheries_courses/2738.asp.

Fig. 4. Electrofishing through rapid survey of fish size-class measurements; this technique was has been established in Greece since 2003. Source: HCMR Upper Aliakmon 2009.

Cathode design

The cathode does not have an attraction zone and in fact repels fish (a property used in fish exclusion screens). However, fish in close proximity to the cathode may suffer tetanus and injuries. To avoid this effect the electric field from the cathode should be very diffuse (Beaumont *et al.*, 2002).

At present, the most commonly used cathode type is the copper braid. It is easily transported, usually left static in the river for stream bank equipment or dragged behind the backpack operator or boat. It has a large surface area and therefore small resistance.

If the cathode is too small, its resistance will be high and an intense field will be created. Increasing the size of a copper braid or using multiple braids improves the cathode efficiency and thus allows more of the circuit voltage to be available at the anode. If it is too large it may be impractical, especially in the case of backpack equipment; where the cathode is usually dragged behind the operator. For copper braids a length of 3 metres or shorter but multiple widely separated braids is optimal.

For very conductive streambeds where more direct electrical coupling of the streambed and anode may occur (resulting in high circuit currents that might overload the fishing gear) floating cathodes should be considered. Caution is needed as the electric shock risk to operators may increase with this type of gear. If possible, the upper surface should be constructed of non-conductive material, for safety reasons.

Water conductivity and fish

As well as affecting the power demand of the electrofishing gear, water conductivity will affect how the electric field affects fish. More accurately, the ratio between the water conductivity and the fish conductivity will affect the amount of power transferred into the fish and thus its reaction. If fish conductivity differs from the respective water conductivity, fish will distort the electrical field thus affecting the power transfer trough their body. Power

Transfer Theory terms this conductivity ratio as the ‘mismatch’ ratio. When water and fish are of the same conductivity this ratio is at its maximum (value 1) and optimal power transfer will take place. If the fish has a lower conductivity than the water, the current will find it easier to travel around the fish rather than through it. Conversely, if the fish has a higher conductivity the current will find it easier to pass through the fish than the water. These mismatch situations will require the current to be varied to compensate for the mismatch. This variation is carried out by adjusting either or both the applied voltage and the pulse duty cycle.

Stream bed characteristics

Substratum type affects electrofishing surveys in a variety of ways. Fish may seek cover or be immobilised under rocks and boulders. Soft sediments could increase the effective depth of the channel and reduce visibility. Care should be taken where there may be saline sediments (e.g. in tidal euryhaline zones) as these can create electrical coupling between the electrodes and cause the electric gear to overload. Similarly, if metallic pipes, metallic reinforcing, fencing or garbage are present in the channel, proximity with the electrodes and particularly contact with the anode should be avoided, as they will again overload electric gear.

Channel size

The depth and width of a site can affect the outcome of electrofishing surveys. Standard equipment is not suitable for deep-water channels due to the comparatively small fishing field, compared with water volume and depth, making fish capture difficult or allowing fish to easily escape. Special equipment (Boom-Boat) should be used together with long handled nets for such situations.

In wide channels fish might escape to the sides of the electrical field. In such cases using two anodes or dividing the channel with lane nets can be used for more successful fishing. Generally one anode is needed for each 5 m of channel width. However, using more than two anodes requires specialized, often high power generation capacity, gear and experienced operators trained in using multiple anode equipment.

Water temperature

As mentioned above, water conductivity will increase proportionally to water temperature. Per degree Celsius, approximately a 2% increase in ambient conductivity is observed. Temperature also affects fish conductivity in a similar manner.

The response of fish to electricity is affected by water temperature as a result of physiological and behavioural reasons. Beaumont et al. (2002) explains how those reasons affect the electrofishing efficiency. In low temperatures fish burrowing below rocks and boulders may be observed. In high temperatures fish activity is increased, thus fish are more alert to escape the electric field and immobilisation is harder to achieve. Mortality caused by stress could be increased under such circumstances, especially post capture.

Different species react differently to temperature variations, however to avoid limited efficiency and limit harmful effects in fish, extreme temperature conditions should be avoided. Although it is largely unknown how each different species react, and acclimatization could vary responses of the same species in different environments, distinctions between salmonids and cyprinids can be made. A temperature range between 10-20°C should be preferred for coarse fish and 10-15°C for salmonids (Beaumont *et al.*, 2002)

Fish related effects

Electrofishing does not influence fish in a uniform manner. Size, species, conductivity, water clarity and position of fish within the electrical field are synergistically influencing fish response to electricity.

Fish species and size

Reaction to voltage, pulse frequency, pulse width and water temperature varies between different species. Some species, like eel are particularly difficult to capture. Injury and mortality rates also vary. The effectiveness of electrofishing on a specific species depends on the fish conductivity, behavioural traits and habitat preferences (i.e. burrowing).

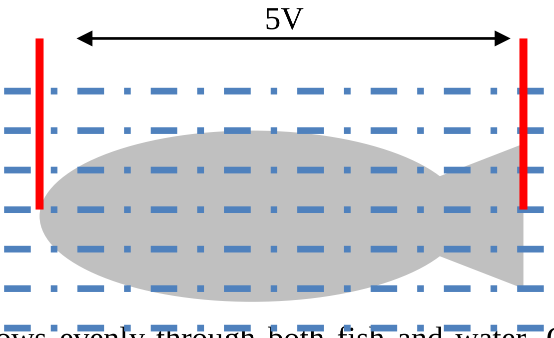
Fish size (volume) is a key variable in controlling the immobilisation thresholds in fish, with larger individuals responding better to electrofishing (Dolan & Miranda, 2003, Helfman, 2007). For smaller species, smaller anodes creating more intense electrical fields may be more effective. However, caution is needed as, in this case, the concentrated field could cause injuries to larger fish that may be present. Smaller anodes can be used in surveys targeting fish fry.

Fish conductivity

The body of the fish acts as an electrical conductor. However, fish conductivity may differ from the conductivity of the surrounding water, carrying the electric field around it, thus distorting the electrical field and influencing its effectiveness.

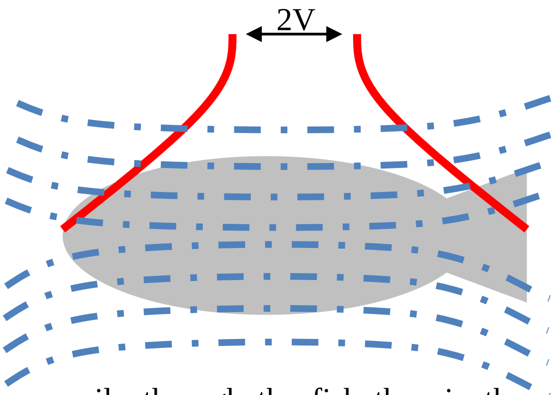
Similarly to water conductivity, water temperature affects fish conductivity in a proportional manner.

a. **<u>Water conductivity (Cw) = Fish conductivity (Cf)</u>**



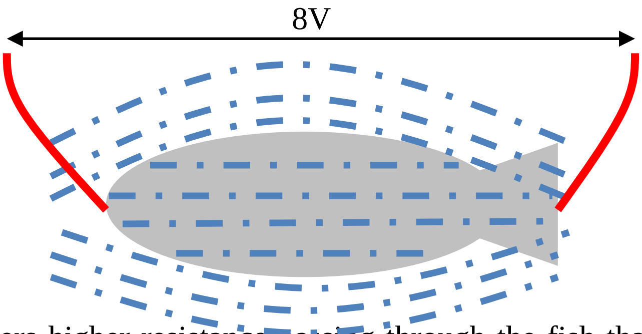
Electrical current flows evenly through both fish and water. Optimum power transfer into fish and voltage field gives (for example only) an optimal 5 Volts head-to-tail voltage.

b. **<u>Water conductivity (Cw) < Fish conductivity (Cf)</u>**



Electricity flows more easily through the fish than in the water around it. Fish distorts current and only 2Volts head-to-tail voltage is applied into fish. Circuit voltage will need to be increased to achieve optimal value.

c. **Water conductivity (Cw) < Fish conductivity(Cf)**



Current encounters higher resistance passing through the fish than the water, leading to its passing around the fish instead of through it. Higher (potentially damaging) head-to-tail voltage, it is recommended to reduce voltage.

Fish orientation

Whether the fish is facing towards or away from the anode (or sideways on) will affect how it reacts to the electrical field. Fish facing the anode will have a more positive taxis towards the anode, that makes capture easier.

Other parameters

Water turbidity, aquatic vegetation and current velocity also play an important role on the effectiveness of electrofishing (see Fig 5). In turbid waters, streambed visibility may be reduced and affect fish capture/collection efficiency. Turbidity might be a characteristic of the site or caused by the personnel during operation. To avoid the latter phenomenon fishing in an upstream is obviously preferred (and this should be practiced in the overwhelming majority of sampling applications).

Aquatic vegetation may alter water chemistry. Moreover, fish might seek refuge or become entangled in weeds, reeds and intense aquatic vegetation. Repeated exposure to electrical shocking may also occur in this case, therefore increased risk of fish injury, especially if vegetation is affecting operator's visibility. In these situations specific fishing techniques can be used to improve drawing fish from refuge areas (DC current). Finally, high water velocity may affect fishing effort and efficiency by making stunned fish harder to collect. A downstream placed net may be useful under such circumstances.

Table 5. Summary of factors influencing the electrofishing effectiveness [adapted from Beaumont *et al.*, 2002; Helfman, 2005; Hill *et al*. 2005]

Output Settings and Gear characteristics	Site characteristics	Fish related	Sampling effort and conditions
Output strength	Water conductivity	Fish size	Time of day
Current density	Channel size	Fish species	Skill of operator
Electrical waveform type	Stream bed	Fish conductivity	Skill of netting personnel
Pulse frequency	Water temperature	Proximity to anode	
Pulse width	Aquatic vegetation	Orientation to anode	
Electrode design	Water velocity		

4. Practical Aspects

Equipment description and safety characteristics/guidelines

Electrofishing equipment:

- Control Box
- Power supply: Batteries for portable backpack units, generators usually for streambank or boat units
- Electrodes: An anode, used to attract and immobilise fish (positively charged electrode) and a cathode (negatively charged electrode, does not have attraction potential)

For safety and fish welfare reasons electrofishing equipment must be built in compliance with all relevant National and EU standards. Modifying electrical equipment is not favoured, as it might distort completely the characteristics of equipment, leading to extreme fish injuries as well as operators risks is not allowed.

Attention should be given to insulation and cables, plugs and sockets. All electrical components must be suitable for use within water. For boat surveys proper grounding of all metal equipment is necessary.

It is essential that all electrical equipment should be well maintained and regularly checked for mechanical and electrical faults. Electrical safety maintenance should be carried out every six months/ annually (or according to manufacturer). An annual full generator service is necessary. Maintenance may only be conducted by nominated or suitably qualified personnel. If faults are observed the equipment must be immediately taken out of commission. Repairing faulty equipment should not be attempted by inexperienced personnel.

Each equipment component must be labelled appropriately, i.e. a zigzag electricity symbol should indicate the potentially hazardous nature of high-tension electricity.

During survey the electric fisher's manual (and/or equipment user's manual), providing guidance on correct settings and safety guidelines should be available.

Power supply

- The only appropriate power supply sources are batteries and suitably modified generators. The electrofisher must never be powered by a domestic supply from the national grid.
- The power source must be connected via the control box. Direct feeding to electrodes should never occur.

Batteries

- Batteries must be non-spill able, i.e. gel-type batteries.
- Carrying back-up batteries to the field is advisable.

Generators

- Electrofishing generators must be manufactured or modified to be used specifically, and only, for electrofishing.
- The output from the generator must not be earthed.
- Contact between the generator and its frame must always be prevented. The generator must be properly isolated from the frame.
- Contact with any other electrical component, such as exhausts must also be prevented.
- An "off" button that automatically switches off the generator should be in place, in addition to the control box's on/off switch. A double pole switch should be preferred (EIFAC).
- The equipment's design must ensure that electricity is transported into the water only via the electrodes.
- Liquid fuels should be stored and transported in safe containers.

Control box

- The control box must be water and shock resistant (IP56 Rated).
- All components, including sockets and control knobs must be electrically isolated.
- A display, placed on the control box, should indicate when the unit is energised. Feeding power to the electrodes must not be automatic. At least one safety control unit switch should be placed on the control box. However the flow of electricity to the electrodes must be prompted by a press-release control switch placed on the anode and in addition to the control box switch. The control box design must never allow independent energising of electrodes.
- A large "off" button must be placed on the control box to cut the power supply from the generator, if needed.

Cables and connectors

- All cables, plugs and sockets must be reserved only for electrofishing purposes.
- Cables should be damage resistant and covered by an appropriate overheat material.
- Cable extensions and connectors may only be used at the control box and the generator.
- Plugs and sockets must be water proof and lockable. Interchanges between cables and plugs/sockets must not occur.
- Colour coding may be useful.

Electrodes

- The construction material of the actual electrode should be highly conductive metal preferably stainless steel. If made of aluminium or copper they should be regularly cleaned to remove the (insulating) oxide layer that will build up.
- For safety reasons the handle should be made from non conductive material.
- If dip net anodes are used the net should be made from non conductive material.
- A press-release control switch (dead man's switch) should be fitted on the non-conductive part of the anode. When both the switch on the control box and the generator are activated, the dead man's switch will trigger flow of electricity into the water. On/off switches and buttons must never be used to avoid an accidental electrical shock.

- Throwable anodes may be exempted from the requirement for a safety dead-mans switch. If throwable anodes are used when electrofishing, it should be ensured that the power cord, used to retrieve the anode is made from strong, insulating material. The cord should be regularly inspected for wear and tear signs. Throwable anodes should not be fitted with a dead man's switch. This makes them unsuitable for wading surveys due to their higher accidental shock potential.

Backpack equipment

Backpack electrofishers (usually powered by re-chargeable batteries) are the most popular and widespread machines in use for streams and small, shallow water bodies (Fig 5).

- Only commercially bought electrofishers, may be used.
- Only gel batteries may be used as a power source for backpack equipment.
- A quick release harness must be fitted on the design to enable rapid removal.
- Tilt and float switches must be placed on the control box, to interrupt the flow of electricity whenever the electric fisher is tilted more than 45^{o} from upright position, or when the unit comes in contact with water. Many modern machines have these devices.

Fig. 5. Typical battery powered backpack electrofishing set up. [Figure adapted from U.S. Pat. No. 5,214,873: Electrofishing pole.]

Land-based Generators

In deeper waters and when using skiffs, small boats or tote-barges stationary generators are usually used since they provide much more power and can be fuel-powered giving much more time to field work. The gasoline-powered generators obviously make much noise and operation must be carefully coordinated among workers; hand signals are commonly used to communicate among experienced workers (Fig. 6).

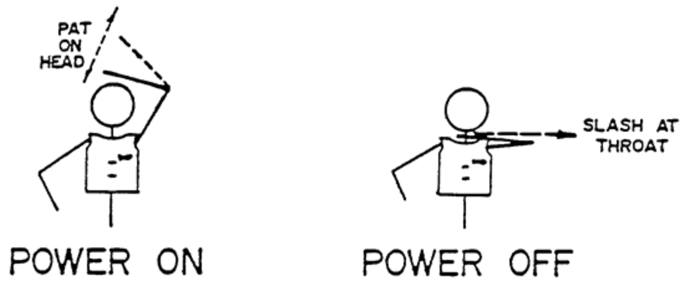


Fig. 6. Hand signals should be organized standardized and used around noisy equipment such as gas-powered electrofish generators. Source: http://www.smith-root.com/support/kb/electrofishing-hand-signals/

Boats

When river, canal or wetland conditions do not allow for wading, a variety of boat-craft may be used in electrofishing. These may vary from small punts or row-boats, to large custom-made skiffs and boom-boats. The tote-barge is an in-between solution, where the generator and associated materials float on a small barge and are tugged along by field workers.

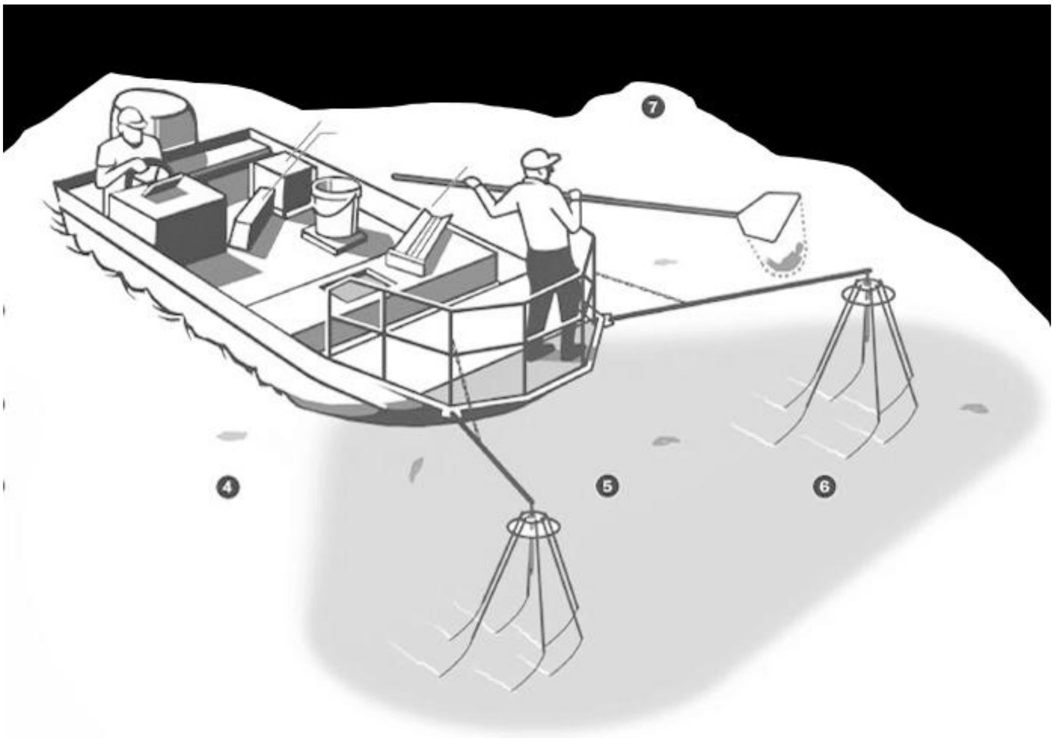


Fig. 7. Boom-boat electrofisher used for deep-water electrofishing. Interpretive schematic from: http://www.washingtonpost.com/wp-srv/special/metro/urban-jungle/pages/130430.html

Guidelines on boat characteristics and working on a boat

- All metal components, i.e. generator frame fuel tanks engine must be electrically connected together.
- Boats should be large enough to accommodate all equipment and crew members without overcrowding.
- Stability that enables crew movement is required.
- The deck must be covered with an anti-slip surface.
- The electrical equipment must be secured against accidental moving.
- Outboard motors should have non conductive engine covers.
- Gears and steerage systems should be insulated.

Fig. 8. Electrofishing through the use of a generator electrofisher set on a small tote-barge which is pulled along by the operators. Holding buckets and other tools (such as a measuring board) are also on board the tote. Source:
http://www.casterbridgefisheries.co.uk/environmental-monitoring/electric-fishing/

Other fishing equipment

Fishing equipment to support an electrofishing operation may include a great variety of materials. Care is needed to use such materials in the presence of electricity. Buckets, hand-net handles and fish containers must be constructed from non-conductible material (plastic). The use of stop-nets is usually optional and has not been implemented in many routine bioassessment procedures; yet in depletion surveys they are very important. For daytime fishing polarized sunglasses help in locating stunned fish. Also more fish are obviously spotted and captured when the team has three individuals in the water rather than two.

Sometimes a combination of tools will be used, especially in biodiversity conservation surveys (i.e. where conditions are difficult or where electrofishing is of limited effectiveness). In such qualitative or semi-quantitative assessments investigative tools such as fry-nets, gill-nets, fyke-nets, cast-nets, fish-traps and snorkelling have proven effective as complements to electrofishing.

5. Fishing with electricity

Selecting Electrofishing Method

Site morphology and water flow conditions, at the time of sampling, determine the type of electrofishing gear suitable for sampling. Table 6 shows the basic guidelines for gear selection.

Table 6. Recommended selection of suitable electrofishing gear (adapted from EIFAC (b)).

Site Details		Suitable Methods			
Width (in m)	Mean depth (in m)	Wade[*1]	Boat	Boom Boat	Single anode
< 5	< 0.8	✓			✓
5 – 8	< 0.8	✓			✓
8 – 15	< 0.8	✓			
> 15	< 0.8	✓			
< 5	> 0.8		✓		✓
< 15	> 0.8		✓		
> 15	> 0.8		✓	✓	

[*1] - Soft sediment which may increase effective depth.
[*2] - Using more than one boat is only permissible if all electrodes on all boats are operated by a single control unit.
[*3] - Wading with two anodes is only permissible if one dead man's switch turns on the whole system.
[*4] - For size variations within the same site it may be necessary to use both wading and a boat to complete the survey.

Electrofishing by wading

Fishing by wading should only be used when water level, in the majority of the site, is less than thigh level. Presence of soft sediments will increase the effective depth and should be taken into account when choosing methods.

There are three gear options for electrofishing by wading:

1. Backpack fishing - Single anode only. Never use two backpack electrofishers at the same time.
2. Fishing with handheld electrodes connected to streambank equipment with long cables.
3. Mounting the control unit and generator on a boat that is towed or pushed behind the electrode operator.

Number of anodes

One anode is sufficient for rivers up to 5 metres. A second anode is required for efficient fishing for rivers up to 10 metres and a third one for rivers up to 15 metres. Increasing the number of anodes increases the power demand, however in a lesser extent than using larger electrodes. When the anode number is increased the cathode area should also increase accordingly. Otherwise the anode's voltage output will be limited. If multiple anodes are used, operators should have been trained in their safe use.

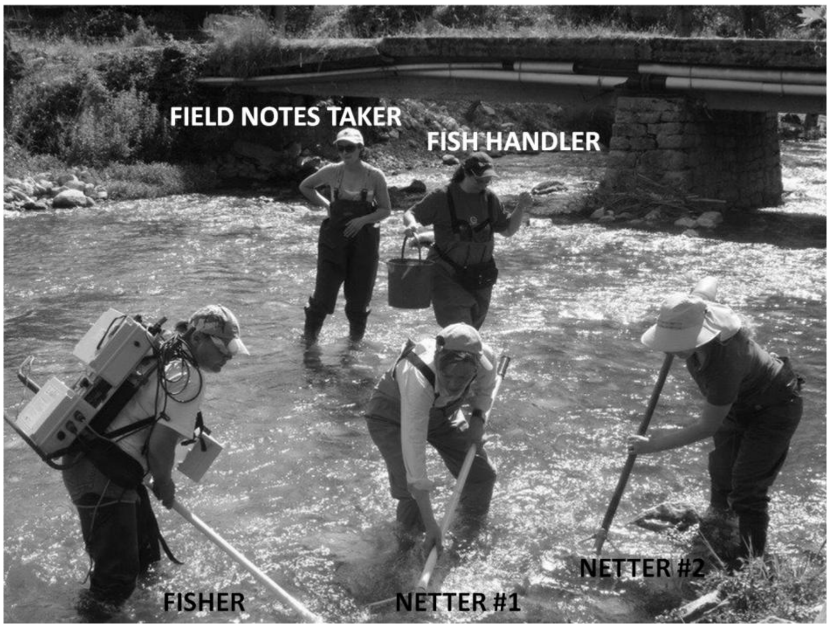


Fig. 9. Five-person field team sampling operation in a 10+ m. wide stream; although one "fisher" is using a single anode, due to the fast-flowing shallow waters two "netters" are employed. The "fish handler" carries a bucket to collect specimens. In terms of experience, the "fisher" and "field note taker" are most important in such an operation. Source: HCMR (2012 Certification course).

Field team size

Team size depends on gear used, site size, expected number of fish and way of fishing (double handed: anode and net or single handed: anode only)

For safety reasons a minimum of three people is required. Depending on fishing strategy (double or single handed), site size, and expected numbers of fish an extra person might be needed for netting. A maximum of five people may participate if fish are to be collected for laboratory examination or other purposes. Each member of the group should be assigned certain tasks throughout the expedition.

If streambank generator gear is used, a team member with ready access to the control unit and generator should also be situated on the bank.

For backpack gear, it is possible for two people to carry out the survey if all of the following conditions are met:

- Operators are very experienced in electrofishing surveys.
- A single backpack unit is used.
- A risk assessment has been carried out at the site before the survey.
- Mobile communication with the base is established.

The table below presents appropriate team sizes.

Table 7. Recommended team size for various electrofishing methods. [source: EIFAC, Draft (b)]

Method	Minimum Team Size	Optimum Team Size	Notes
Wading: backpack	3	4	Two people can operate the equipment if they are experienced, a risk assessment has ensured the suitability of the site, a single backpack electrofisher is used, and mobile communication with the base is established.
Wading: single anode	3	4	1. Single handed fishing or large expected number of fish may require more nets in which case the minimum number is 4. 2. A staff member with ready access to the electrofisher should be placed at the bank.
Wading: double anode	4	5/6	1. One or two people should be holding nets and one a fish bucket. 2. For streambank gear, A staff member with ready access to the electrofisher should be placed at the bank.
Boat: handheld single anode	3	5	1. If working double handed a three member team may be sufficient under certain circumstances. 2. If working single handed five people are required.
Boat: handheld double anode	4	5	1. If working double handed four people are required.. 2. If working single handed five people are required.
Boom boat	3	4	Additional nets might be needed when large number of fish is expected
Boom boat & catcher boat	5	6	

Electrical output settings

As mentioned above, effectiveness of electrofishing relies on a variety of factors. Output settings must be made according to local conditions.

Voltage, pulse frequency and pulse width should be initially set to the minimum recommended for the water conductivity at the site and then be increased if fish response is limited. Using higher voltage will not necessarily increase fish capture, but it will increase tetanising properties. Adjusting one of the output parameters while keeping the others unchanged should be attempted to check the fish response. The electrical output should be kept at the minimum that elicits fish response, particularly if vulnerable species are present.

To make the appropriate settings the following steps should be followed:

1. Measure Water Conductivity
2. Convert Specific to Ambient Conductivity (if a Specific Conductivity meter is used).
3. Set Voltage according to Ambient Conductivity
4. Set Pulse Frequency (for PDC waveforms)
5. Set Pulse Width/ Duty Cycle (for PDC waveforms)
6. Check fish response
7. If needed adjust one of the above parameters within the appropriate limits (see below).
8. Avoid exceeding limits, to increase fish response adjust a different parameter

Water conductivity

Most conductivity meters measure the Specific Conductivity this is temperature corrected to 25ºC. However, to set the correct voltage output we need the value of Ambient conductivity (i.e. the actual conductivity at the temperature of the water).

Converting Specific to Ambient conductivity may be achieved either by using the ElectroCalc spreadsheet, a lookup table (Table 8), or by using the following function:

- $Ca(t) = Cs\ [1+0.023^{(t-25)}]$,

  where :

  Ca(t) = Ambient conductivity at a certain temperature

  Cs = Specific conductivity

  t= ambient temperature.

Table 8. Specific to Ambient Conductivity Conversion Table

Specific Conductivity at 25 °C (µS.cm-1)	Temperature (°C)				
	5	10	15	20	25
50	32	36	40	45	50
100	63	71	80	89	100
150	95	107	119	134	150
200	127	142	159	179	200
250	159	178	199	223	250
300	190	213	239	268	300
350	222	249	279	312	350
400	254	284	319	357	400
450	286	320	358	402	450
500	317	355	398	446	500
550	349	391	438	491	550
600	381	427	478	536	600
650	412	462	518	580	650
700	444	498	558	625	700
750	476	533	597	669	750
800	508	569	637	714	800
850	539	604	677	759	850
900	571	640	717	803	900
950	603	675	757	848	950
1000	635	711	797	893	1000
1050	666	747	836	937	1050
1100	698	782	876	982	1100
1150	730	818	916	1026	1150

1200	**761**	**853**	**956**	**1071**	**1200**
1250	**793**	**889**	**996**	**1116**	**1250**
1300	**825**	**924**	**1036**	**1160**	**1300**
1350	**857**	**960**	**1075**	**1205**	**1350**
1400	**888**	**995**	**1115**	**1250**	**1400**
1450	**920**	**1031**	**1155**	**1294**	**1450**
1500	**952**	**1066**	**1195**	**1339**	**1500**
1550	**984**	**1102**	**1235**	**1383**	**1550**
1600	**1015**	**1138**	**1275**	**1428**	**1600**

Voltage output

Voltage effectiveness varies with ambient water conductivity, waveform type and the size of the effective capture field.

The lower the conductivity, the higher the voltage required to elicit fish response. It is recommended to start fishing at the lowest range of the voltages presented in the table below (Table 9).

Table 9. Recommended settings of Voltage output
(ASSUMING MAXIMUM EFFECTIVE CAPTURE FIELD IS DESIRED)
[Adapted from EIFAC(a) : Beaumont et al. 2002].

Conductivity (µS.cm^{-1})	Voltage (V) - PDC	Voltage (V)- DC
<150	250 – 300	300 – 400
150 – 500	200 – 250	250 – 300
500 – 800	150 – 200	Not applicable
800 – 1000	120 – 180	Not applicable
> 1000	100 – 150	Not applicable

Pulse Frequency

The effectiveness of pulse frequency mostly depends on fish species. The table below presents the optimal frequencies based on attraction and immobilization potential, as well as fish welfare. DC current is not mentioned, as frequency is not applicable in this case.

Table 10. Setting the Pulse Frequency
(For optimum combination of attraction, immobilisation and welfare)
[Sources: Scottish Fisheries Co-ordination Centre, 2007: Beaumont et al. 2002]

Species	PDC – Frequency (Hz)
Salmonids	40 – 60
Cyprinids	30 – 50
Percids	10 – 40
Pike	30 – 50
Eel	10 – 40

Pulse Width/ Duty Cycle

Pulse width determines the duration of a pulse. Increasing pulse width will increase the current and power consumption. For fish welfare and power conservation, pulse width should be kept to a minimum. Below you may find the recommendations expressed in duty cycle for a 40-60 Hz pulse frequency (Table 11) and milliseconds (Table 12). Duty cycles greater than 50% should be avoided.

Table 11. Recommended Duty Cycle (%)

Conductivity ($\mu S.cm^{-1}$)	Duty Cycle %
<150	10
150 – 500	10 – 20
500 – 800	10 – 30
800 – 1000	10 – 40
> 1000	10 – 50

Table 12. Recommended Pulse Width in milliseconds
[Source Bill Beaumont, personal communication: ElectroCalc]

Conductivity ($\mu S.cm^{-1}$)	Pulse Width (ms)
<150	2 – 5
150 – 800	3 – 8
800 – 1000	5 – 10
> 1000	7 – 15

6. Ways of working: Technique in Electrofishing

Fish collection techniques for scientific surveys have been published in several manuals (see Coad, 1998). Here we refer to some aspects of working with electrofishing equipment.

Equipment inspection

Before any survey trip, electrofishing equipment should be visually inspected, paying particular attention to the generator, electrical control gear and cable insulation.

Once on site, establish and follow a system for checking equipment. The system must include checks on the mechanical operation of safety switches before the equipment is energised. The list below describes what to check:

- Check the plugs and sockets, to ensure that they are correctly fitted and seal fully tightened.
- Do not use any item of equipment, if any part of it appears to be damaged or not working correctly
- If the result of the electrically dead examination is satisfactory, start the generator, with the electrodes immersed in water.
- Check the operation of the systems and safety switches before actual fishing begins.
- Never energise fishing electrodes unless they are immersed in water

Advice on standardised European methods and protocols for electrofishing may be found in: European Standard EN 14011:2003 Water quality – Sampling of fish with electricity (Anon 2003).

Technique details

Good electrofishing technique is important, particularly when carrying out standardized forms of monitoring and when attempting population assessment using catch depletion methods. This is because the method assumes constant catch effort approaches. If this is not the case then the statistical interpretation of the data may be biased or invalid. Too low or too high capture efficiency can also lead to very wide or overly narrow confidence limits around the estimate or inaccurate estimates (Bohlin 1982). Good technique can also reduce the effort required for population estimation by removing the need to carry out additional fishing runs (Kruse et al.1998).

Before actually fishing a site, a plan and risk assessment, as explained above, should be expressed. This should include factors such as access to the water, water depth and flow, danger from slippery substrate or sharp rocks etc. All team members should be briefed as to their roles and communication signals agreed. Only then should electrofishing commence.

If electrofishing equipment is to be bank-based, a level area for the generator should be found and the generator should not be moved when it is running. The location should ideally be near fast flowing water where the cathode should be placed. This ensures that any fish incapacitated by the cathode are carried away. The anode cable should be laid out so that it does not tangle (spread-out over a large area is less likely to tangle than tight coils). Water conductivity at the site should be measured and the appropriate anode size and output settings determined and set-up. Test of equipment should be carried out with all electrodes immersed to avoid the dangerous situation of electrodes being energised when out of the water. If the site or conditions are different (e.g. conductivity) to those previously experienced, an area outside the survey reach should be fished to check that the settings used are both not harmful but still catching fish.

Employing “surprise” and tactics in electrofishing

Capturing fish can be enhanced by introducing the element of surprise through intermittent fishing and employing special tactics. These methods are really quite widespread and widely promoted in the literature and by experienced field workers (Smith-Root, undated). The intensity of the anode's peripheral field often frightens fish, causing them to bolt and hide. Do not work with the power on continuously, but turn it on only in likely habitats. Fish can be enticed from under areas of heavy cover by inserting a portable anode, turning the power on, and withdrawing the anode slowly and smoothly. Fish will follow the anode, under the influence of galvanotaxis, into the open where they can be netted. ‘Feathering’ (quickly switching the anode on and off) is also a useful method of increasing the drawing effect of the anode (in cases that PDC is used). “Holding areas” (i.e. refugia) should be fished from the edges in so that large numbers of fish are not suddenly encountered. Anode operators should fish discontinuously so that fish are not driven ahead of the anode. Likewise, in weed beds or undercut banks, if the anode is placed in clear water close to these areas, it will draw the fish out of the areas where netting may be difficult.

Clarity and depth of waters

Clarity of the water limits the ease of capturing fish. Fish can obviously perceive the electrofishing team from a far and some species (e.g. salmonids) will take cover in deeper waters. The length of the dip-net handles and the visibility of the fish limit the depth of effective electrofishing. In general, waters over 3 meters deep cannot be sampled effectively. Low-conductivity waters also make electrofishing more difficult.

Netting fish

Fish should be netted in order to enable identification, processing (we promote rapid assessment here) and quick release behind the up-stream progressing electrified area. Netting needs skill but may be quickly learned. When fishing with minimum output required, as to just incapacitate the fish, then even greater netting skill is required. In these conditions the fish are often very fast moving and only weakly incapacitated, near the anode. Speed of reaction and good hand-eye co-ordination is needed for efficient netting. Netting tetanised fish is easier, but so is netting dead fish and this is not usually desired. The most common cause of missing fish is too slow reactions or netting over the top of the fish due to parallax errors in seeing the fish. Fish should not be held in nets for any length of time and should not be kept in nets whilst netting further fish from the electric field.

When netting fish, care needs to be taken not to hit other workers with the net poles. Grievous injury can be caused in this manner, especially if the end of a net pole is pushed into the face of another member. If net operators are inexperienced then some thought should be given to provide eye protection to those who may be in the close area of the net (bucket carriers etc). Plastic polarizing glasses will give some protection and help to see the fish. Cable holders and bucket carriers should also not crowd the anode and net operators (often a temptation in order to see what is happening). This will increase the possibility of being hit and limit the movement of the net operators, if they need to swiftly move in any direction.

7. Types of electrofishing survey

Areal coverage

An important issue that affects key aspects of assessment and survey is the area covered at a site's electrofishing application. For general surveys, the length of river that needs to be fished to achieve a adequate representation of the fish composition will vary with stream size (or water body size). In streams, such aspects are more easily standardized. In general a length of at least 20 times the streams width should be fished. For small rivers the whole of the stream should be fished, but for large rivers (>15m width) just 100m of one bank can be fished (considered "partial whole" fishing strategy).

In fact, in streams the following fishing strategies may be defined:

"whole": sampling scheme covered all fish habitat present at the site, including both river banks and mid-channel, and the majority of selected site area was sampled (usually sampled in a zig-zag pattern wading upstream).

"partial whole": sampling scheme covered most fish habitat present at the site, including both river bank and mid-channel habitats, but still a considerable proportion of the selected site area was not sampled.

"one bank": sampling scheme covered only fish habitat present at the bank of the river. Most of the selected site area wasn't sampled.

"ambient": sampling scheme covered only patches of the site, resulting in poor overall cover but specific habitat coverage (usually all habitats are covered well). However, usually only a small portion of the selected site area was actually sampled since the fisher "skipped" ahead and attempted to do a "representative" sampling concentrating on all habitats present.

"other": define any other sampling scheme applied.

It is crucial that the areal extent of the stream waters that are electrofished be carefully estimated; also the length must be carefully measured (using paces) and recorded. A sketch-map of the area sampled is a good method of guiding a more consistent recording of these important parameters.

Quantitative or semi-quantitative sampling

Quantitative surveys use population estimation techniques where formulae are applied to catches from a series of repeat samples, to calculate an estimate of the population for each species caught.

To satisfy the conditions of the catch depletion estimation method, the site being fished should be isolated with stop nets and/or natural barriers, and the whole length and width of the site must be sampled. In this case a site has to be sampled at least three times unless:

- the second catch is far much smaller than the first and the field estimates of population size indicate:

- that the population size exceeds 200 specimens;
- and/or that the probability of capture of an individual fish is greater than 60%.
- Under these circumstances a third sample needs not be carried out. These conditions cannot be absolutely prescriptive, but will be closely approached where the first catch exceeds 120 fish and / or the second catch is less than or equal to 40% of the first. High probabilities of capture will always reduce the likely benefits of a third fishing, no matter how many fish are present.

It is essential that fishing effort remains constant throughout all fishing runs.

In monitoring applications, such as the fish-based sampling for WFD, a semi-quantitative approach may be applied, but effort must be exerted to maintain consistency and standardization.

For WFD sampling, surveys should meet the following requirements:

- Single run, between topographic “barriers”, if possible, in the channel (e.g. two natural barriers/landmarks separating distinct habitat feature in the lotic channel or stop-nets could be used).
- Survey at least 100m of river length or at least 10 times the wetted width and an area coverage of at least $100m^2$
- All fish species present should be caught and identified to species level.
- An effort must be made to cover the entire channel as best as possible; therefore a “whole channel” sampling strategy is usually desirable.

Qualitative sampling

Surveys that collect qualitative information employ conventional sampling, usually from a single electrofishing run. They are characteristically less intensive or consistent than semi-quantitative approaches. Where estimates of the likely probability of capture (catch efficiency) are available (e.g. from other quantitative surveys on similar types of river), these surveys can become semi-quantitative by applying the catch efficiency multipliers to the single removal data.

Note: Stop nets are often not necessary and in routine sampling are often not used. However, if the survey intends to interpret any sort of density attributes or probability of capture as a population estimator, the sampling site should be “isolated” at least by natural barriers (such as riffles, rapids, waterfalls or other habitat break-points in the channel formations).

Fig. 10. Sampling with a back-pack electrofisher along the shore of a small lake can only be a "qualitative form" of sampling since reaching larger-sized fishes, and some deeper-water inhabitants is usually not possible. In this clear-water reservoir fish are stunned and collected only where they may seek cover or by surprise. Source: HCMR WFD monitoring (Photo: I. Karaouzas, Lake Beletsi, Attika).

Rapid look-see surveys

It should be mentioned that a very rapid sample (less than 5 mins) and covering less than 100 m^2 may also be important and can usually be used to apply a look-see approach (i.e. to "observe what's there"). Look-see is a valid application in many terrestrial survey techniques and obviously should not be underestimated as an important survey approach. These rapid surveys should always be documented in a field form similarly as to every other qualitative and quantitative survey.

Timed surveys

Timed surveys may be used at sites to standardize catch effort or where conventional removal sampling is not practical. For example, they can be used to estimate comparative data where large numbers of fish are present (particularly small-sized species) or to give comparative data where quantitative fishing is not possible e.g. where boom-boat electrofishing offers the only practical sampling method. Surveys are typically taken over a 5 minute period, whilst boom boat sampling may take much longer. Certain backpack and pulse box units have the facility to monitor the 'on-time' of the fishing gear and cut out when a set limit has been reached. This type of timing is of benefit as it then excludes (the variable) fish-handling time from the time period.

The results obtained are expressed as numbers of fish caught per minute; the Catch Per Unit Effort / Time (CPUE/T). CPUE/T data provide a useful and repeatable comparative index where sampling conditions preclude any other approach. Full details of the site (length, width, etc) should be carefully recorded. At completion of sampling all gear that has been in the water should be disinfected and stored dry, particularly if sampling different water catchments.

8. Conservation and animal welfare issues

Fish welfare

Ethical aspects arise when sampling aquatic animals. Fish are vertebrates and experience pain and stress. Electrofishing is much less disturbing than many other invasive techniques of sampling (e.g. netting, long-lining etc.) and certain institutions have promoted rapid survey techniques, evolved to minimise stress, injury and unnecessary death (e.g. size-class rapid assessment). As fish welfare issues become more widespread, practitioners must adjust their methods to minimise stress impacts on fish (Huntingford et al 2006, Braithwaite 2010). Some scientific journals will not publish manuscripts if specific measures are not taken to prevent undue suffering to fish specimens during collection.

Some basic ways to minimise stress on fish during electrofishing and fish collection practice include:

- Field workers who collect fish must be well-informed and trained on the issues of wildlife and fish welfare issues and the correct handling of live fish for research purposes.
- Proper electrofishing and collection training optimises fishing effort while minimising injuries. “Burn-marks”, spinal deformalities and death of some specimens are far more likely when fish are over-exposed to electricity or when settings of voltage, pulse width etc. are inappropriately set.
- Special care of sensitive species and sensitive specimens. Larger individuals may need more time to recover after shock.
- Not using a netted anode is one way to minimize undue electrical shock. This should be considered especially when species that exhibit poor population abundance or sensitive species, e.g. isolated salmonid populations.
- Care must be taken when sampling not to disturb ‘special habitats’. An understanding and sensitivity to fish habitat needs is all that is required to avoid unnecessary action (trampling, fouling water etc) that may disrupt or displace large numbers of young fish, reproductive micro-habitats and other sensitive environments for fish (and other wildlife).
- Clove-oil as an excellent anaesthetic for sample collection, to minimise stress and pain. It is widely used before fish are sacrificed or fixed as specimens for collection.

Conservation Issues

There is little doubt that electrofishing can be damaging to some fish species populations if it is practiced in a negligent manner. It goes without saying that electrofishing is also a widespread form of poaching, especially in the Balkan countries, so its unregulated impact can have devastating effects on some fish (e.g. on salmonids). Even scientific electrofishing can locally disturb fish so special care is needed. It is therefore important to promote best-practice and exhibit special care for conservation, especially in areas where threatened, protected or declining fish populations are being sampled.

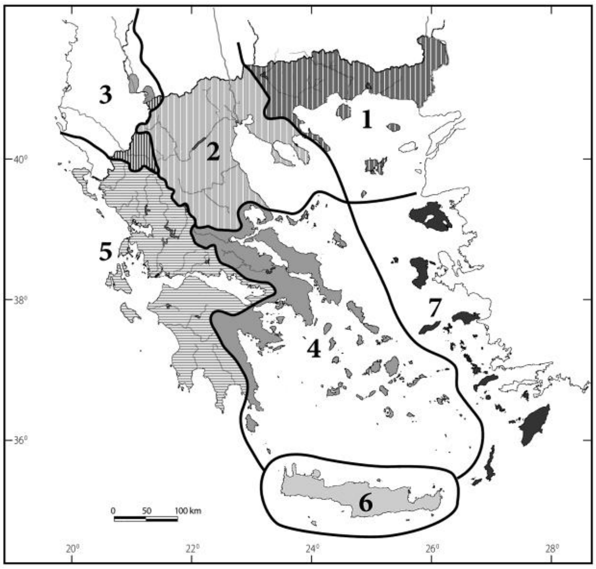
Important issues on this manner reflect the following:

- Illegal electrofishing is a big problem in the Balkans and every effort must be made by scientists to avoid its ‘promotion’. When practicing electrofishing for scientific sampling one should actively communicate to inform locals that the illegal practice of electrofishing can be extremely destructive, if practiced by poachers or amateurs.
- Practice careful disciplined display of scientific work in view of locals. Never give fish to locals who may want to eat them; or take fish home for food. This prevents a ‘hidden message’ that electrofishing is an effective and easy way to provide for food.
- Take special care not to injure or kill particular fish species or specimens in a rapid assessment operation. Check to see if there are a fish-deaths associated with the sampling. With modern electrofishing equipment and trained personnel fish death/ fish injury should be minimal.
- Spreading non-indigenous species through equiptment contamination is an ‘ecological crime’ especially if this is done through sloppy action by scientists (see below). Workers should be trained and drilled to practice routine disinfection/cleaning of all fishing equipment that may carry fish or other animal and plant material among fishing sites.

Biological contamination and the spread of non-indigenous species

A much-neglected issue in Greece and other Mediterranean countries is the risk of contaminating the native biota with non-indigenous species, carried unintentionally with nets and other sampling equipment used for fish surveys. The risk is highest when working survey teams cross biogeographic boundaries such as drainage basins or ecoregion boundaries (Fig 11). Extreme care must be exercised to clean and disinfect the equipment including boots, nets etc between fish sampling work. Particular disinfectants can be purchased in bulk quantities and widely used for this purpose.

Fig. 11. Biogeographic freshwater ecoregions are important in helping maintain/contain biological pollution from unintentional spread of “biological contaminants”, due to surveys that move among more than one river basin or ecoregion boundaries. Freshwater ecoregions delineated on this map are: 1) Thrace, 2)Macedonia-Thessaly, 3) SE Adriatic, 4) Western Aegean, 5) Ionian, 6) Cretan, 7) Western Anatolian (Eastern Aegean). Source: Zogaris (2009).



Licenses, species-protection and communication

In order to obtain license to collect fishes specific license is needed from specific authorities (In Greece, the Hellenic Ministry of Rural Development & Food). This is not usually granted if the work is not relevant to a particular need. It should be noted that 72 species of freshwater fish found in Greece are of European Union conservation interest (mentioned directly and indirectly in the EU Habitats Directive Annexes). Many of them are characterized as threatened on a global scale (Legakis and Maragou 2009).

PART 3

USING THE HCMR

RAPID ASSESSMENT PROTOCOLS

1. Using the HCMR protocols

Two basic field forms are used for ichthyological surveys in rivers, streams and other inland water bodies by the HCMR sampling teams. These protocols are provided in Appendix 2.

These protocols aim to meet WFD monitoring requirements and the majority of sampling survey requirement for other purposes (e.g. fish community descriptions, conservation status assessments). These basic sampling protocols includes the following two field forms:

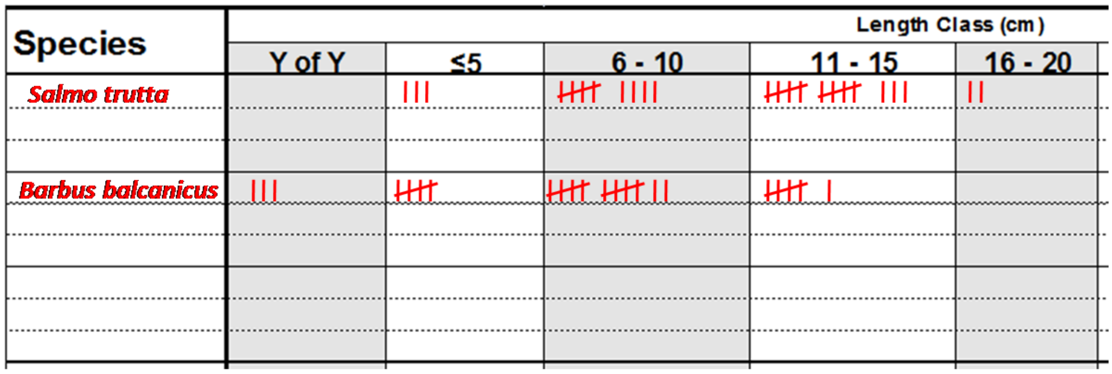
- HCMR size-class fish-list field form
- HCMR rapid fish sampling field form

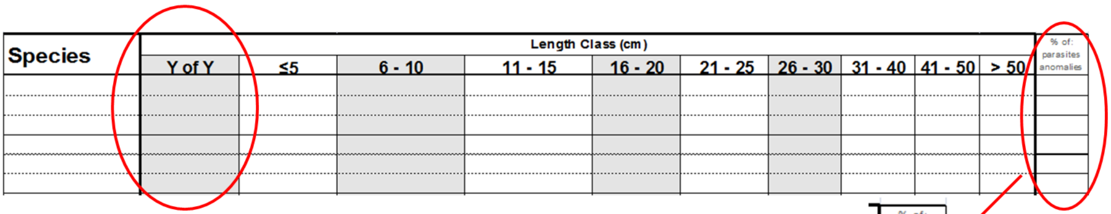
Both of these have been adapted from sampling protocols applied in other European countries and slightly modified to suit specific needs in Mediterranean inland water conditions (particularly for but not limited to lotic conditions). The size-class approach was adopted in 2003, in accordance to respective German protocols (from a collaboration with U. Dussling), and the site-based rapid fish sampling field form was developed from widely used field forms used in Portugal and Germany (c/o M.T. Ferreira, U.Dussling). The protocols were adapted, tested and refined both during the EU FAME project and during the monitoring implementation of the WFD in Greece and Cyprus and they have been used in other Mediterranean countries as well.

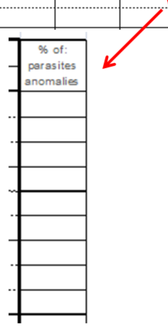
It should be noted that both protocols are intentionally rather simple and flexible in their structure, in order to be practical for both monitoring purposes and investigative or exploratory sampling surveys. In fact, the protocol use is not limited to electrofishing sampling surveys or sampling in rivers; these recording formats have been successfully used to document fry-net sampling, seine-net sampling, snorkelling surveys and fishermen's catch interviews. Although they are originally destined for lotic waters; they can be used in lacustrine and wetland conditions. When using these field forms in areas away from lotic environments attributes that are not filled-in since they may be irrelevant to non-lotic conditions are noted with the term N/A (=Non-Applicable).

HCMR size-class fish-list field form

This field form is a simple list of the fish species and their numbers collected (or encountered and/or observed) in a sampled area of any water body. Specimens are recorded in size-class categories. This rapid tally approach to recording differs from the traditional approach used during traditional population surveys in electrofishing (i.e. where all fish are removed, maintained in oxygenated containers, anaesthetized and counted/weighed individually employing fine-scale measurements). The size-class approach works very rapidly; fish are caught in the net and measured using a scale on the anode or hand-net pole – and immediately released behind the fisher. The fisher proceeds working upstream and does not re-catch shocked fishes. Individuals are recorded in the appropriate column according to their size-class in cm (total length). Size classes include provision for young-of-the-year (YofY).







• Y of Y column: "young of the year", the individuals born in the latest reproductive period within the same year as the survey.
• % of: parasites, anomalies: estimation of the percentage of fish, for each species, with parasites/anomalies within the total catch, for the respective species

Note that apart from the fish numbers per species an estimate of % of fish that had any kind of disease, conspicuous parasite effects or anomalies is noted in the outer right column. (This attribute has proven to be important as a metric of stress on populations often by human pressures such as water pollution).

The top section of the protocol is used to record only the basic information of the sampled site (Site name, River, Date) so that there will be restricted repetition of data documentation since the "HCMR Rapid Fish Sampling Field Form" necessarily is also always filled-in alongside this protocol.

Site name:	**River** or **Waterbody:**	**Date:** ....

Any specific notes or specific observation can be jotted on the bottom panel or overleaf. Notes of condition of the fish or other species' encounters should be recorded here; however the accompanying "HCMR rapid fish sampling field form" also provides space for habitat-use data, interviews etc.

Notes ➡

HCMR Rapid Fish Sampling Field Form

This field form has been developed in order to make a rapid but in-depth assessment of sampling site characteristics, including structures that affect habitat for fish populations (Appendix 2). It is routinely applied with the "HCMR size-class fish-list field form" and in no case should the latter be used without this. This standard field form should be filled out immediately after the sampling operation and requires one to survey the sampled reach carefully and rapidly (this field inspection and the recording of the details should take no more than 20 minutes).

The boxed section on the top of the front page of the protocol is dedicated applied method description (i.e. non-habitat related information).

HCMR Rapid Fish Sampling Protocol		
1. Researcher:	**2. Fisher:**	**3. Completed by:**
4. Sampling Site: Name	Code	**5. Date:**
6. Hydrographic Basin:	**7. Course:**	
8. Location Description: (nearest village; distance from bridges, etc. ......)		**9. Reference site** Yes ☐ Near ☐ No ☐ estim. on site
10. GPS Coordinates	**11. Time:** Start: Finish:	**12. Altitude:** **13. Slope:**
14. Sampling Equipment: equipment type: ... ... manufacturer: ... ... electricity: DC ☐, PDC ☐, other: ... ... mean Volt: ... ... , mean frequency:	**15. Sampling Effort:** A B C D comments: ... ... * if "C":sampling data will be used under provision, *if "D": sampling data will be considered incomplete, or qualitative, * regarding sampling conditions e.g. equipment eficciency, complete habitat cover, difficulties due to flow regime, deep water, turbidity that reduce fishing efficiency etc.	
16. Sampling strategy: a) whole ☐ partial whole ☐ one bank ☐ ambient ☐ other: ... ... b) wading ☐ boat ☐ wading + boat ☐ other:		
17. Fished length (m):	**18. Fished area** (m^2):	**19. Flow regime:** Permanent ☐ Intermittent ☐ Ephemeral ☐

Fields **1-3**: Fill-in name of the lead researcher/ers (researcher = team leader of the expedition), the name of the person operating the fishing gear (fisher) and the name of the person who is filling-out the field form, accordingly.

Fields **4-5**: Fill-in site name (and code) of the sampling station and the date of the survey. The "site name" is often different from the alpha-numeric code (usually the code is given later and must conform with official monitoring/survey points kept in databases). The site name should be unique to the site and memorable. (If the same site is sampled on another occasion exactly the same site name should be given; however, if a slightly different site area is sampled even within the same river reach another name should be given).

Fields **6-7**: Fill-in the name of the hydrographic basin first (this pertains to the hydrographic basin unit (i.e. river basin area). Then fill-in the name of the river course (i.e. river tributary) or water body section if in lake or wetland.

Field **8**: Describe the sampling station location, directions, access guidelines or problems reaching the site.

Field **9**: Check "**Yes**" box for reference sites (minimum human impact along entire river section); "**Near**", meaning "Near Reference", when only minor impacts and human degradation have altered the conditions; and "**No**" for non-reference sites, where anthropogenic impacts are obvious (even if conditions are in "good" state). If a site is pristine or in near-natural condition it may be important to explain and provide assessment criteria for this in the comments overleaf.

Field **10**: GPS coordinates for the sampling station location.

Field **11**: Starting and ending time of the sampling survey (to estimate survey duration) when electrical equipment is used to catch fish.

Fields **12-13**: Fill-in altitude and longitudinal gradient slope of the sampling station, if the appropriate equipment exists. Otherwise these must be filled-in back in the office.

Field **14**: Describe the type and characteristics of the equipment used for the survey. In case of electrofishing surveys, give waveform type (DC: direct current, PDC: pulsed current), voltage and frequency used. If the frequency and voltage varied give the mean values. In case the survey was not carried out (as in all non-applicable fields) write down "N/A" over the field query.

Field **15**: Rate the sampling effort. This is a product of many parameters, such as equipment efficiency, complete habitat cover, difficulties due to local conditions (flow, water depth, turbidity etc.) that affect fishing efficiency. Additionally, sampling effort evaluation should always consider the total number of fish caught - in the sense that sampling data must be adequate for statistical analysis. If numbers of fish caught are lower than expected for the particular location and river type one must describe details in relevant field over-leaf.

The following four-level scale of effort rating is used and interpreted as follows:

A Site sampled completely in best possible effort and sampling conditions. This category includes quantitative (depletion method) or semi-quantitative sampling, in the sense that all fish habitat were sampled and all fish species and their relative abundance, in the fish community, has been well documented by a high degree of effort.

B Site sampled rather well; almost best-possible effort and sampling conditions (e.g. sites with some deeper parts that were not sampled or flow conditions and turbidity of water made sampling effectiveness not uniform). This category includes semi-quantitative sampling, in the sense that all fish habitat was sampled adequately, all fish species has been captured but their relative abundance, might deviate slightly from actual conditions.

C Site sampled inefficiently. Not all fish habitat present were sampled adequately and conditions or time invested was not adequate for a very good semi-quantitative sample. Still, in most cases sampling data might be representative, as far as fish species and their relative abundance is concerned (e.g. the site was not efficiently sampled but the specific river stretch is inhibited only by a few species). Additionally, this category includes sites that by definition cannot be sampled adequately, by any sampling method, strategy or effort (e.g. big or deep or fast flowing rivers), so sampling conducted was the best possible.

D Site sampled poorly, too rapidly and/or definitely in an incomplete matter. This category includes formal as well as informal sampling methods and strategies, which usually reveal only qualitative aspects of the fish community (e.g. wading only small patches of the river, wading and writing down rough numbers of fish being collected, fishes recorded from a recreational fishermen's catch, or from observations with binoculars from the bank or from a bridge etc.).

Use the comment section to write down the reason of reduced efficiency (weather/flow conditions, equipment deficiency etc.). Data collected with a sampling effort rated as C will be used under provision. Data collected with a sampling effort rated as D will be considered incomplete or usable only for qualitative purposes.

Field **16**: Choose among the sampling strategy options:

a) This field refers to method of coverage along a longitudinal section of any lotic water body (river, stream, canal or other artificial channel form). In non-lotic environments these distinctions are usually also relevant; if conditions do not warrant such description please label "N/A" (Non Applicable).

"whole": sampling scheme covered all fish habitat present at the site, including both river banks and mid-channel, and the majority of selected site area was sampled (usually sampled in a zig-zag pattern wading upstream).

"partial whole": sampling scheme covered most fish habitat present at the site, including both river bank and mid-channel habitats, but still a considerable proportion of the selected site area was not sampled.

"one bank": sampling scheme covered only fish habitat present at the bank of the river. Most of the selected site area wasn't sampled.

"ambient": sampling scheme covered only patches of the site, resulting in poor overall cover but specific habitat coverage (usually all habitats are covered well). However, usually only a small portion of the selected site area was actually sampled since the fisher "skipped" ahead and attempted to do a "representative" sampling concentrating on all habitats present.

"other": define any other sampling scheme applied.

b) Check the appropriate box if sampling was conducted by:

"wading": if the fishing crew was conducting the survey moving on foot through the stream (usually upstream).

"boat": if the fishing crew was conducting the survey in a boat.

"wading+ boat": if the fishing crew was conducting the survey using a combination of the two previous mentioned techniques.

"other": define any other sampling technique that has been used. (Combinations of technique must always be given (i.e. snorkelling & inspection of fisher's catch).

Fields **17-18**: Fill out the sampled river length, in meters (m). This is the total longitudinal channel distance from start to finish (even if sections in-between may have not been sampled adequately; i.e. in ambient-type sampling). The "fished area" is carefully estimated in square meters (m^2). The fished area one of the most important fields to be measured since it gives a "sense" of population density (and a potential measure of CPUE) in surveyed reaches.

Field **19**: Check the lotic water bodies' flow regime that best describes the sampling station's flow conditions. Perennial refers to streams that do not dry-out at all even during summer (although during exceptional drought years some perennial reaches may be reduced to pools or have desiccated river bed portions). Intermittent stretches dry-out for a definite period during the dry season (usually at least 2 months) but small pools may remain. Ephemeral refers to water course carrying water only for short period after precipitation or snow-melt (these usually do not have fishes!).This is estimated by expert judgment (inspection of hydrological characteristics, stream-bed morphology and in-stream and riparian vegetation).

Assessing the habitat

In fields 20-22 record information regarding site dimensions

20. SITE DIMENSIONS

Width (m)	
Wetted width	
Left bank up to water	
Right bank up to water	

* mean of the site

21. WIDTH (m)

<1	%
1≤L<5	%
5≤L<10	%
10≤L<20	%
≥20	%

*reference to the fishing area

22. DEPTH (m)

<0.25			%
0.25≤P<0.5			%
0.5≤P<1			%
≥1			%
⇩		⇩	
Mean		Max	

*reference to the fishing area

Field **20**: Note the mean width of the sampled site in meters in the ‘’wetted width’’ box. This refers to the whole site’s stretch not only the specific sampled area, basically giving an impression of the whole reach of the site (See Appendix 1 for diagram). In the ‘’left bank up to water” and ‘’right bank up to water’’ boxes, looking downstream, estimate the mean width of the active channel (from the water’s edge to the point up to which river flows during highest discharge). When these three attributes are summed we get a sense of the width of the river’s “main channel” (See Appendix 1 for diagram).

Field **21**: Estimate the percentage composition of width extent of the sampled site. If sampling is conducted in a braided section of the river give the respective percentages referring to the entire width of the braided channel (this will also be reflected in field 20).

Field **22**: Percentages are assigned to depth classes, to represent the depth conditions. Mean and maximum depths are also recorded (estimated by practitioner on site; to the best of his/her ability). The practitioner may choose if measurements refer solely to the sampled area or to the river site area. If the measurements the site was sampled using the “whole” strategy this field refers automatically to the river site area. Fill the appropriate column (or both columns) using a careful on-site estimate. (* One way to help estimate visually-estimated water depth is to physically mark a depth scale on boots and waders).

23. SUBSTRATE (%)

Rock continuous		Sand <2mm	
Boulder >256mm		Silt	
Cobble 64-256mm		Clay	
Pebble 16-64mm		Organic	
Gravel 2-16mm		Artificial	

*reference to the sampling area

24. SHADEDNESS (%)

* canopy cover over sampling area

25. WEATHER

Sunny ☐ Cloudy ☐ Rainy ☐ other: … … … … … * prevealing conditions of the last few days

Field **23**: Fill in respective percentages for each substrate type, to represent the sampled area's substrate composition.

Field **24**: Write down an approximation of the canopy cover over the sampled area.

Field **25**: Check the appropriate box (or otherwise specify) for the weather conditions referring to weather conditions of the last few days, if this has an effect on sites hydrological conditions (especially after heavy rainfall or long periods of rain).

26.VELOCITY

< 0,1 m/s	
0,1-0,25 m/s	
0,25-0,5 m/s	
0,5-0,75 m/s	
0,75-1 m/s	
> 1 m/s	

* estimated mean velocity

27. PHYSICOCHEMICAL MEASUREMENTS

Conductivity (mS/m)		T⁰ of air (⁰C)	
Diss.Oxygen		T⁰ of water (⁰C)	
pH		Salinity	

Turbidity: clear ☐ slight turbid (>1m)☐ turbid (<1m)☐ very turbid ☐

28. HELOPHYTES

Missing	
Isolated Rare	
Sparce	
Intermidiate	
Rich	
Dominating sp.:	

* note with an X

29.BOTTOM VEGETATION

Missing	
Sparce	
Intermidiate	
Rich	
Dominating:	

* note with an X

30. HABITAT TYPE (%)

Pool (deep/still)	
Glide (shallow/move)	
Run (deep/move)	
Riffle (shallow/rough)	
Rapid (steps/fast)	
Other.....................	

*reference to the fishing area

31.Important Pressures:

Field **26**: Check the appropriate box describing the mean velocity of the flow of the sampling site (m/s stands for meters/seconds). This can be visually estimated by throwing a floating object in the water.

Field **27**: Complete the box with the values measured for each physico-chemical element. Mark only the elements measured (Water temperature and conductivity should be imperative). Check the appropriate box for turbidity.

Fields **28** & **29**: Check the appropriate box representing the presence of helophytes (Field 28) and bottom vegetation –referring to submerged vegetation (Field 29) at the sampling site. For description of vegetation characteristics see appendix (below). Note the dominating species if any (i.e. the species that are most abundant in terms of areal cover).

Field **30**: Assign percentages to each habitat type to quantify habitat composition of the fished area. This must be done carefully and it should reflect the site scale (this would be identical to "site scale" assessment if the whole or ambient sampling strategy is adopted).

Field **31**: List important pressures, present at the sampling site. This refers both to previously known pressures or environmental degradation from any source of information (interviews etc). Also any pressures observed during the sampling survey.

32.Fish habitat Details: spp number: ☐

32a. Habitat types sampled

logs/large woody debris		undercut banks	
overhanging vegetation		thick root mats	
dense macrophyte beds		marshy fringes	
deep pools		isolated/backwater pools	
boulders/ cobbles		riffles	
other natural cover types: … … … … … … … … …			

* note with an X

32b. Efficacy of habitat sampling

1 poor cover	
2	
3 adequate	
4	
5 excellent cover	

* note with an X, expert judgment

33.Other Notes/ Interviews:(hydrology, modifications, pollution, introductions, historical fish presence, fishing methods&activities)

Field **32**: In the blank rectangle note the number of fish species collected and/or observed during sampling. Give notes on habitat-use of fishes or any other ichthyological observations.

> **32a**: Check box for every one of the habitat features sampled. Write down any features that are not included on the list.
>
> **32b**: Assign a score from 1 (poor cover) to 5 (excellent cover), assessing the efficiency of the sampling effort in covering all the habitat types that are present in the site, using expert's judgment.

Field **33**: Write down any other significant notes or interviews with locals. Here you may want to mention other fauna and flora observed or any outstanding observations (particularly environmental/conservation related aspects).

34.Site drawing:

Upstream

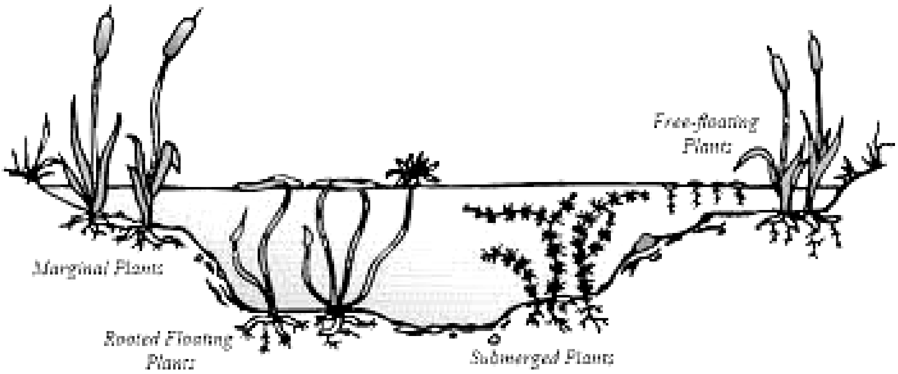
Downstream

Basic sketch: form of channel, other important features (pools, riffles, deep pools, backwaters, small dams or obstacles), fishing strategy.

Field **34**: Make a clear sketch of the morphological feature of the sampling site, adding important elements such as habitat and vegetation cover; and shading areas that were fished/sampled.

APPENDIX 1

Water plants (helophytes vs. submerged “bottom plants”)



The HCMR protocol refers to both “helophytes” and “bottom plants”. Helophytes refers to emergent marginal plants rising high above the water and muddy shore (such as the *Juncus sp., Carex sp, Phragmites sp. Typha* sp. in this diagram). In cases where semi-aquatic or terrestrial grasses and forbes are flooded – they should be also considered as emergents – but these must be rooted in the water. “Bottom plants” refers to submerged and floating aquatic plants (including rooted floating plants). Source: Urban water quality plants http://pubs.ext.vt.edu/426/426-044/426-044.html.

Channel characteristics

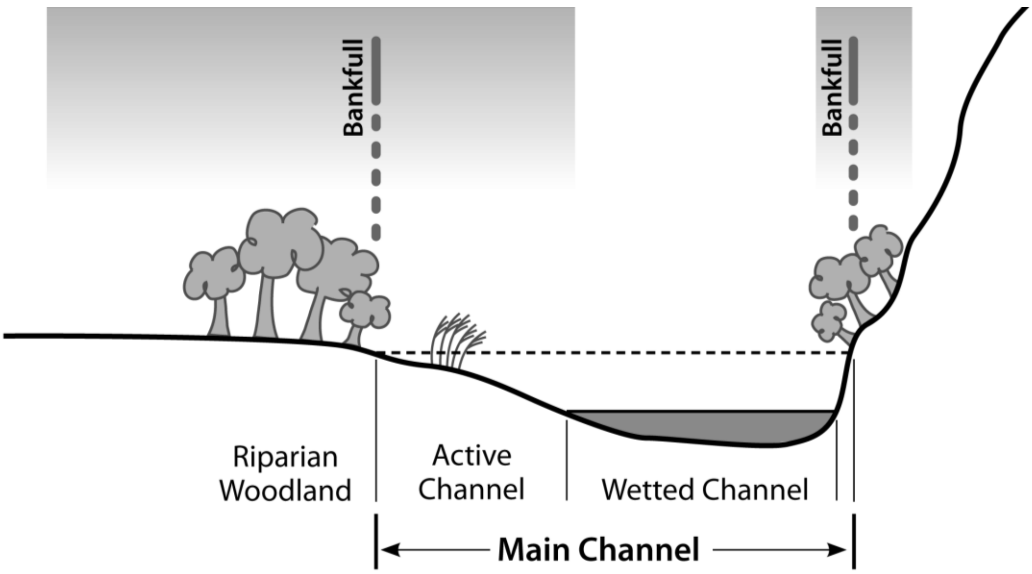


Diagram showing emphasizing differences among riparian area (shaded) and main channel of the river corridor. The main channel can be conveniently conceived as area having a wetted portion and an active channel portion delimited by regular bankful flooding. (Fig. S.Zogaris & A. Vidalis).

APPENDIX 2

Complete Protocols

HCMR // Rapid Ichthyo-Assessment Protocol

1. Researcher:	2. Fisher:	3. Completed by:

4. Sampling Site: Name	Code	5. Date:
6. Hydrographic Basin:	**7. Course:**	

8. Location Description:

(nearest village; distance from bridges, etc. ......)

9. Reference site
Yes ☐
Near ☐
No ☐
estim. on site

10. GPS Coordinates	11. Time: Start: Finish:	12. Altitude: / 13. Slope:

14. Sampling Equipment:
equipment type: ... ...
manufacturer: ... ...
electricity: DC ☐, PDC ☐, other: ... ...
mean Volt: ... ... , mean frequency: ... ...

15. Sampling Effort: A B C D
comments: ... ...
* if "C":sampling data will be used under provision, *if "D": sampling data will be considered incomplete, or qualitative,
* regarding sampling conditions e.g. equipment eficciency, complete habitat cover, difficulties due to flow regime, deep water, turbidity that reduce fishing efficiency etc.

16. Sampling strategy: a) whole ☐ partial whole ☐ one bank ☐ ambient ☐ other: ... ...
b) wading ☐ boat ☐ wading+boat ☐ other: ... ...

17. Fished length (m): | **18. Fished area** (m²): | **19. Flow regime:** Permanent ☐ Intermittent ☐ Ephemeral ☐

20. SITE DIMENSIONS

Width (m)

Wetted width	
Left bank up to water	
Right bank up to water	

* mean of the site

21. WIDTH (m)

<1	%
1≤L<5	%
5≤L<10	%
10≤L<20	%
≥20	%

* in braided channels refer to the sampling area

22. DEPTH (m)

	sampling area	site area
<0,25	%	%
0,25≤ P <0,5	%	%
0,5≤ P <1	%	%
≥1	%	%
	Mean: (m)	Mean: (m)
	Max: (m)	Max: :(m)

23. SUBSTRATE (%)

Rock continuous		Sand <2mm	
Boulder >256mm		Silt	
Cobble 64-256mm		Clay	
Pebble 16-64mm		Organic	
Gravel 2-16mm		Artificial	

*reference to the sampling area

24. SHADEDNESS (%)

* canopy cover over sampling area

25. WEATHER

Sunny ☐ Cloudy ☐ Rainy ☐ other: ... ...

* prevealing conditions of the last few days

26.VELOCITY (m/sec)

< 0,1	
0,1 - 0,25	
0,25 - 0,5	
0,5 -0,75	
0,75 -1	
> 1	

* estim. mean velocity

27. PHYSICOCHEMICAL MEASUREMENTS

Conductivity (mS/m)		T^0 of air (^{0}C)	
Diss.Oxygen		T^0 of water (^{0}C)	
pH		Salinity	

Turbidity:clear ☐ slight turbid (>1m) ☐ turbid (<1m) ☐ very turbid ☐

28. HELOPHYTES

Missing	
Isolated Rare	
Sparce	
Intermidiate	
Rich	
Dominating sp.:	

29.BOTTOM VEGETATION

Missing	
Sparce	
Intermidiate	
Rich	
Dominating:	

30. HABITAT TYPE (%)

Pool (deep/still)	
Glide (shallow/move)	
Run (deep/move)	
Riffle (shallow/rough)	
Rapid (steps/fast)	
Other....................	

*reference to sampling area

31.Important Pressures:

32.Fish habitat Details:

spp number:

32a. Habitat types sampled

logs/large woody debris		undercut banks	
overhanging vegetation		thick root mats	
dense macrophyte beds		marshy fringes	
deep pools		isolated/backwater pools	
boulders/ cobbles		riffles	
other natural cover types:	…	… … … … … … … …	

32b. Efficacy of habitat sampling

1 poor cover	
2	
3 adequate	
4	
5 excellent cover	

* expert judgment

33.Other Notes/ Interviews:

(hydrology, modifications, pollution, introductions, historical fish presence, fishing methods & activities etc.)

34.Site drawing:

Upstream

Downstream

basic sketch: form of channel, other important habitat features (pools, riffles, deep pools, backwaters, small dams or obstacles), fishing strategy etc.

Site name: ……………………………… **River** or **Waterbody:** ……………...………... **Date:** ……………………

Species	Length Class (cm)										% of: parasites anomalies
	Y of Y	**≤5**	**6 - 10**	**11 - 15**	**16 - 20**	**21 - 25**	**26 - 30**	**31 - 35**	**35 - 40**	**> 40**	

Notes ➡

Notes:

Glossary

Abundance	The number fish found in a population. See also relative abundance.
Alternating current	Cyclic bidirectional current, a sequence of positive and negative waves, alternating for equal time periods. Not used in electrofishing.
Ambient conductivity	Value of the conductivity of water at the ambient temperature.
Anode	The positive electrode, usually attached to a non conductive pole/handle. The anode creates the electric field that attracts fish when placed in the water.
Backpack electrofishing	The fisher operator carries a mobile electrofishing machine on his back, powered by batteries. The cathode trails behind the fisher.
Boom-boat electrofishing	Generator electrofishing gear is placed on a boom-boat, with fixed electrode array, not operated by hand.
Cathode	The negative electrode. Should always be placed in the water during electrofishing gear operation. Does not create an attraction zone, but it creates a field potentially harmful for fish.
Conductivity (electrical)	The ability of a certain material or element to conduct an electric current. Reciprocal of resistivity.
Continuous Direct Current (DC)	Uniform unidirectional current. It does not have a negative component (unlike the alternating current).
Current (electrical)	Quantity of electrical charge flow in a circuit per unit of time.
Current density	The value of the electric current per unit area. In electrofishing usually measured in Amps per square centimeter (A/cm^2).
Deadman switch	A pressure switch that supplies electrical current to the circuit when pressed.
Depletion method	In inland waters fish surveys the depletion method consists of multiple fishing runs, to temporarily remove from a sampling site, in order to make a quantitative assessment.
Dip–net anode	An anode electrode with an attached non-conductive mesh, enabling netting and lifting fish.
Electrical conductance	Ease with which electricity passes through a certain material.
Electrical resistance	Opposition of a certain material to the passage of an electric current.
Electrical resistance	The opposition of a certain material to the flow of an electrical current. Measured in Ohms (Ω).
Electrofishing	The use of electricity to attract and immobilize fish for easy capture.
Emergency off switch	Immediately cuts of electrical supply.
Fish conductivity	The measure of the fish's body ability to conduct electricity.
Fisher/operator	The person that uses the anode electrode.
Galvanotaxis	"Voluntary" swimming towards the anode, caused by the current induced stimulation of the central nervous system of the fish.
Generator	Fuel powered machine that produces electrical current. Needs to be especially designed for electrofishing purposes.
Grounding	Connection between an electrical circuit and the earth.

Habitat	The environment in which an animal or plant species usually lives or grows. And as “Habitat type” a distinct type of environmental space with characteristic abiotic features and conditions supporting specific biotic assemblages.
Narcosis	The narcosis zone (in DC fields only) is the area around the anode where fish become immobilized. Fish muschles are relaxed and breathing is normal. Recovery is observed immediately after the removal from the electrical field. Unlike tetanus, narcosis is not harful to fish (see also tetanus)
Netter	The person who nets the immobilized fish in an electrofishing operation.
Power Transfer Theory	Theory explaining how the ratio between fish and water conductivity affects fish reaction to an electric field.
Pseudo-forced swimming	When in close proximity to the anode electrode, swimming towards is induced through muscle stimulation.
Pulse Frequency	The number of pulses generated per second. Measurable in Hertz (Hz).
Pulse width – Duty cycle	**Pulse width** refers to the duration of a pulse, the amount of time when electric current flows through the circuit over a period/cycle. Usually expressed in milliseconds (ms) or duty cycle. **Duty cycle** is the percent of time during a cycle where the power is on and current is transferred though the circuit (e.g. 25% duty cycle).
Pulsed Direct Current (PDC)	Unidirectional intermitted current. Current flows during regularly repeated “pulses”.
Punt fishing	Electrofishing gear is placed on a small boat or skiff (punt). Fishing is carried out using hand held electrodes.
Relative abundance	The number of individuals of a particular species as a percentage of the total number of individuals of all species of a give area or community.
Resistivity (electrical)	A measure of a material or element’s ability to resist the flow of electric current.
Specific conductivity	Value of the conductivity of water at a standard temperature (usually 25^{o} C).
Standardisation	Promoting use of constant methods and equipment.
Streambank (generator) electrofishing	Electrofishing control unit and generator placed on the stream bank, cathode is placed in the water. A long anode cable is used for fishing as operators wade in the water.
Tetanus	Muscle contraction due to extensive nerve stimulation leading to fish immobilization and respiratory obstruction. Tetanus may occur in AC, PDC and very high DC electric fields a, near the anode. Potentially harfmful for fish. (see also Narcosis)
Tote-barge electrofishing	Generator electrofishing gear is placed on a tote-barge, pulled along by operators.
Voltage	The potential force of electricity: energy per unit of electrical charge. Measured in Volts (V)
Voltage gradient	The rate of change (decrease) in voltage with increasing distance. Usually measured in Volts per centimeter (V/cm).

Cited Literature

Beaumont, W.R.C., Taylor, A.A.L., Lee, M.J. & Welton, J.S. (2002) Guidelines for Electric Fishing Best Practice. Report to Environment Agency 179pp EA Technical Report W2-054/TR

Bohlin, T., Hamrin, S., Heggberget, T.G., Rasmussen, G. and Saltveit, S.J. (1989). Electrofishing - Theory and practice with special emphasis on salmonids. Hydrobiologia, 173:9-43.

Coad, B.W. (1998). Expedition Field Techniques: FISHES. Published by Geography Outdoors: the centre supporting field research, exploration and outdoor learning. Royal Geographical Society.

Cowx, I.G. and P. Lamarque, P. (1990). Fishing With Electricity- Applications in Freshwater Fisheries Management, Fishing News Books, Blackwell Scientific Publications Ltd.

Cowx, I.G. (Ed.). (1991). Catch Effort Sampling Strategies and their application in Freshwater Fisheries Management. Blackwell Scientific Publications.

European Inland Fisheries Advisory Commission (EIFAC a): 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

European Inland Fisheries Advisory Commission (EIFAC b): Working Party on Fish Monitoring in Fresh Waters. Draft: Guidelines for Fish Monitoring in Fresh Waters. Pdf available from EIFAC website: www.fao.org/fi/body/eifac/eifac.asp

Goodchild, G.A. 1991. Code of practice and guidelines for safety with electric fishing. EIFAC Occasional Paper. No. 24. Rome, FAO. 1991. 16p.

Helfman, Gene S (2007). Fish conservation: a guide to understanding and restoring global aquatic biodiversity and fishery resources. Island Press, Washington, DC.

Hill, David Arnold; Matthew Fasham, Graham Tucker, Michael Shewry and Philip Shaw (2005). Handbook of biodiversity methods: survey, evaluation and monitoring. Cambridge, UK: Cambridge University Press. pp. 219–222. ISBN 0-521-82368-4. OCLC 61439712

Huntingford, F.A., Adams, C.E., Braithwaite, V.A., Kadri, S., Pottinger, T.G., Sandoe, P., and Turnbull, J.F. (2006). Current understanding on fish welfare: A broad overview. Journal of Fish Biology 68: 332-372.

Legakis, A. & Maragkou, P. (Eds) (2009). Redbook of endangered animals in Greece. Hellenic Zoological Society, Athens, Greece, 86-159.

Meador, M.R., Cuffney, T.F., and Gurtz, M.E., 1993, Methods for sampling fish communities as part of the National Water-Quality Assessment Program: U.S Geological Survey Open File Report 93-104, 40 p.

Scottish Fisheries Co-ordination Centre, (2007). Fisheries Management SVQ Level 2: Catch fish using electrofishing techniques. Inverness/Barony College, June 2007.

Smith-Root Ltd. (Undated). Introduction to Electrofishing. Manual available at: http://fisheries.btc.ctc.edu/Manuals/Introduction%20to%20Electrofishing.pdf

Zogaris, S., Bjorkland, R., Bjorkland, R.H., Chatzinikolaou, Y., Giakoumi, S., Economou, A.N., & P.Dimopoulos. (2008). Rapid assessment protocols for monitoring in riparian zones. In "Sustainable Riparian Zones: A Management Guide (eds: D. Arizpe, A. Mendes, & J. Rabaca). Pp. 127-141. Generalitat Valenciana, Valencia, Spain. English Edition ISBN: 978-84-482-4967-0.

Zogaris, S. (2009). Contribution to a biotic classification of the rivers of Greece based on ichthyofauna and riparian vegetation. Department of Environmental and Natural Resources, University of Ioannina, Greece. 422 p. (In Greek).

Internet

Vandewoude, S. (Undated) Field biosafety issues in animal wildlife research. http://arssymposium.absa.org/pdf/V-VandeWoude.pdf

About IMBRIW – Inland Waters Department

This field manual was created by members of the Inland Waters Department at the Institute of Marine Biological Resources and Inland Waters (IMBRIW) of the Hellenic Centre for Marine Research (HCMR). HCMR is Greece's largest public research centre for the aquatic environment, functioning under the auspices of the General Secretariat for Research and Technology, Ministry of Education, Culture and Sports. HCMR has three institutes with a wide range of R&D interests that conduct multidisciplinary policy-relevant science in all areas of the aquatic environment.

Members of the current Inland Waters Department of IMBRIW have been working on sampling fish assemblages in inland waters since the late 1980s. This group of scientists has worked on many international and EU funded projects both in Greece and abroad. Institute personnel have helped establish standardized inland waters sampling and monitoring schemes in Greece, Cyprus and the surrounding region. The institute's experience in sampling fish in inland waters has had three basic approaches:

- Sampling for fisheries
- Sampling for biodiversity and conservation
- Sampling for ecological quality assessments

These approaches need standardized methods so surveys can be effectively repeated and can function as rigorous natural history documentation, ecological surveying and monitoring schemes that show trends and assess a variety of changes. Since HCMR personnel have been involved in pan-European methods standardization and intercalibration projects, the aim here is to assist in providing a reference for basic sampling methods. This manual introduces a rapid and effective method developed and tested in many types of inland waters, especially for biodiversity and ecological quality assessments in streams and rivers.

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