Freshwater fish: electrofishing—multi-pass

Version 1.1

This specification was prepared by Michael Lake in 2013.

Contents

Department of Conservation
Te Papa Atawhai

Synopsis

Multi-pass electrofishing is a survey method used to estimate the abundance or density of freshwater fish within a site. The key advantage that the multi-pass method has over other electrofishing methods in the Toolbox is that it can provide quantitative estimates of abundance. These estimates are less affected by variations in catch efficiency over space and time than the catch per unit effort (CPUE) data produced by other electrofishing methods. The multi-pass method is not ideally suited to determining fish community composition in terms of either species presence/absence or relative densities because of the higher level of effort required to use it. The potential for injury of fish is also higher with multi-pass electrofishing because of the number of times fish are exposed to the electrical field if not captured. Like all electrofishing methods it is restricted to sampling habitats that can be safely waded.

As the name suggests, the multi-pass electrofishing method involves electrofishing a site multiple times in succession. Stop nets are used to block movement into or out of the sampling reach. The rate at which catches of fish decrease over consecutive passes is used to estimate overall fish abundance using statistical models, often referred to as removal or depletion models.

Many of the assumptions underlying this method have a significant influence on the precision of the density estimates that are obtained. It is therefore recommended that catch efficiency assumptions and sampling biases be tested for any monitoring programme that uses the multi-pass electrofishing method. If density estimates are not found to be sufficiently accurate then consideration should be given to other sampling approaches.

All backpack electrofishing should comply with DOC's standard operating procedure (SOP) for the safe use of electrofishing machines (see 'Electric fishing: one page SOP'—docdm-676678, and 'Electric fishing technical document—health and safety'—docdm-752861).

Assumptions

Backpack electrofishing:

- Where fish length data are collected, the size structure of fish in the sample is the same as the size structure of the population present within the sample reach. This assumption will be frequently violated as electrofishing tends to be more effective on larger fish (Temple & Pearsons 2007).

Multi-pass method—density estimate:

- There is no movement into or out of the sample reach during the sampling period.
- Catch efficiency remains constant with each pass (Hayes et al. 2007).
- Catch efficiency is the same for all individuals within the sample area (Hayes et al. 2007).

Advantages

- One of the key advantages of multi-pass electrofishing is that density estimates, unlike CPUE data, are less affected by differences in catch efficiency between samples. This makes the method a potentially more powerful monitoring tool where catch efficiency is likely to vary between sites or over time (Hayes et al. 2007).
- Can provide quantitative estimates of absolute abundance of fish, which cannot be provided by other electrofishing or passive sampling methods.
- Can be conducted in larger rivers provided there is enough wadeable habitat that can be sampled.

Backpack electrofishing has the following additional advantages:

- All wadeable habitat types within the stream can be sampled including fast-flowing riffle and run habitats.
- Allows catch per unit effort data to be calculated on an accurately defined area basis, e.g. fish captured per 100 m^2 (Hayes et al. 1996).
- Less affected by water temperatures and turbidity compared with some other sampling methods.
- Relatively low impacts on fish and other instream biota compared with some other sampling methods.
- Samples a greater diversity of fish species than other sampling methods.
- Can be carried out during normal working hours (rather than after dark).

Disadvantages

- If more individuals are caught in the second or third passes than were caught in previous passes then it is not possible to estimate density. There is a risk that time spent collecting data is wasted. This may be particularly problematic for streams containing low numbers of fish.
- The data obtained will not provide reliable density estimates unless critical assumptions are validated in the field (Temple & Pearsons 2007).
- Density estimates obtained by removal methods have been found to be heavily biased by site characteristics, fish species and fish size (Peterson et al. 2004).
- Greater risk of increased mortality or injury of fish due to the length of time some fish are exposed to electrical fields (Snyder 2003).
- Requires stop nets which can be difficult to carry to remote sites.
- Limited to sites where stop nets can be effectively deployed.
- Can be more time consuming than other methods.
- Will not reflect taxa richness unless long sample reaches of 150 m are fished (see ‘Freshwater fish: electrofishing—fixed reach —docdm-755847).

Backpack electrofishing of any type has the following additional limitations:

- Requires specialist equipment and completion of an electrofishing training course.
- Specific fish species capture can require operator and poll net holder experience.
- Limited to sampling in wadeable habitats.
- Potentially size-selective and therefore caution must be used when interpreting length-frequency data.
- Capture efficiency is reduced in habitats with complex structure such as woody debris and dense macrophytes (Portt et al. 2006).
- Capture efficiency is reduced as stream width increases (Portt et al. 2006).
- Capture efficiency is reduced as turbidity increases (Portt et al. 2006).
- Equipment is reasonably bulky and may not be appropriate for remote areas with poor access.
- Capture efficiency is low for nocturnal pool-dwelling species such as kōkopu.
- Capture efficiency is known to vary widely between different species (Portt et al. 2006). This means that relative abundances in electrofishing samples may not reflect actual relative abundances of different species in the sampling reach.
- Capture efficiency is reduced in very low or very high electrical conductivities. The Kainga EFM 300 is designed to work in conductivities between 10 and 400 µS/cm (NIWA Instrument Systems n.d.).

Suitability for inventory

This method is not an appropriate method for acquiring inventories of freshwater fish communities because it is much less efficient than other methods. This can be more effectively accomplished using fixed-reach methods, possibly in combination with other methods in the Toolbox.

Suitability for monitoring

This method is suitable for monitoring where estimates of fish density are a key variable of interest in the monitoring programme. Other survey methods are recommended if presence/absence or abundance indices are all that are required.

Skills

Design and analysis

Staff involved in the development of survey programmes should be familiar with basic principles of good sampling design. ‘A guideline to monitoring populations’ (docdm-870579) will assist with understanding these principles. It is important that input from statisticians is obtained for both the design and analysis phases to ensure that the data collected are scientifically robust. Good statistical design is especially critical for monitoring programmes that may be complex and have high ongoing running costs. It is much harder to improve design after data collection has started or been underway for some time than it is to put time into the initial planning. Putting effort into designing a programme well at the outset ensures that the running costs are justified and will result in useful information that meets the monitoring objectives.

The ability to use a spreadsheet software package such as Microsoft Excel is a minimum skill required for data entry, data checking and analyses. The ability to use statistical software packages is desirable but not mandatory provided support from a biometrician is available. Staff involved in data analysis must be conscious of the assumptions underlying the use of electrofishing machines and removal methods for estimating abundance.

Survey teams

The training required for undertaking electrofishing is outlined in DOC's 'Electric fishing: one page SOP' (docdm-676678) and 'Electric fishing technical document—health and safety' (docdm-752861). A minimum of two certified operators are required to use a backpack electrofishing machine. To be certified, an operator must have completed an 'Electric Fishing for Machine Operators' training course and attended refresher courses at required intervals (contact the DOC Science & Capability Group to find out about these courses). All team members must hold a current first aid certificate and be trained in wader safety.

The survey team should contain at least one person able to identify freshwater fish to species level and one who has experience in handling fish to minimise unnecessary injury or mortality.

Resources

Backpack electrofishing:

- Survey team—a minimum of two certified operators are required to undertake backpack electrofishing (see 'Electric fishing: one page SOP'—docdm-676678, and 'Electric fishing technical document—health and safety'—docdm-752861). In many instances it will be advisable to use three-person teams so there is always someone available to handle fish and record any missed fish. Three-person teams may be needed when time frames are tight or at sites that are overgrown, deeply incised or have uneven streambeds.
- Backpack electrofishing machine. The battery powered NIWA Kainga EFM300 is the standard machine used in New Zealand.
- Waders for all team members. All waders should be checked for leaks prior to fishing. Staff should be trained in wader safety; see 'Wading safely' (olddm-566603) for guidance.[1]
- Pole net.

[1] http://www.doc.govt.nz/Documents/parks-and-recreation/places-to-visit/tongariro-taupo/wade-safely-brochure.pdf

- Dip nets. Typically at least one dip net is used by the operator. In a team of three it is possible for a second or even third team member to also use dip nets.
- Polarised sunglasses for all team members (optional).
- Measuring board (if fish are to be measured).
- Voucher jars for fish samples / fin clips filled with 70% ethanol.
- Linesman gloves for each team member. These must be rated to 1000 V and waterproof.
- GPS unit / NZTopo50 1:50 000 map.
- Water quality field meter(s).
- Rain-proof data sheets with clipboard and pencils, including New Zealand Freshwater Fish Database forms.
- Freshwater fish identification book, e.g. *The Reed Field Guide to New Zealand Freshwater Fishes* (McDowall 2000).
- Measuring tape to measure area fished.
- Wading rod for measuring stream depths (optional).

Multi-pass equipment:

- Stop nets. At least two and sometimes three stop nets are used.
- Live wells. Either buckets or holding bins that can be placed within the stream to allow stream water to pass through without fish escaping.
- A portable aerator may be needed to maintain oxygen levels in the bucket while fish are being processed.

Minimum attributes

Consistent measurement and recording of these attributes is critical for the implementation of the method. Other attributes may be optional depending on your objective. For more information refer to 'Full details of technique and best practice'.

DOC staff must complete a 'Standard inventory and monitoring project plan' (docdm-146272).

The minimum requirements for a fish survey will be largely determined by the objectives of the study or monitoring programme. Careful consideration of these objectives should be made prior to collecting data. However, for any study the following minimum attributes should be recorded:

- The name of the observers who collected the data.
- The date and time of sampling.
- The upstream and downstream ends of the sampling reach must be recorded using an accurate handheld GPS.
- Electrofishing machine settings used including output voltage, pulse width and pulse frequency.
- The number of each fish species caught in each 'pass' should be recorded separately. Any missed fish (fish that are observed but not captured) are not normally used to calculate

abundance; however, it may be useful to record these as missed fish. Kōura (freshwater crayfish) should be recorded and counted in the same way as fin-fish species. Avoid holding kōura in the same buckets as fin-fish as they are highly aggressive and may injure other fish.

- All fish species of interest should be identified to species level. It is envisaged that in many instances only a sub-set of species present at a site will be of interest when multi-pass electrofishing is being used. However, if time permits, all species should be identified and counted as this may yield other useful information.
- Measurement of fish length and fish weight is optional depending on whether population structure and fish condition are key variables of interest for meeting the survey objectives.

It is important to collect habitat data to describe factors that may influence catch efficiency and therefore the key underlying assumptions of the method. Habitat data are also useful when it comes time to analyse data as many habitat variables will help explain why certain results were observed. There are a number of guidelines and protocols available for collecting habitat data. A set of standard national guidelines has been recently developed by Harding et al. (2009).

The minimum habitat variables that need to be recorded include:

- Electrical conductivity
- Water temperature
- Average stream width (calculated from a minimum of 5 measured widths)
- Total length of the sample reach
- Water visibility (good, average or poor)

The collection of the following additional habitat variables is optional but recommended:

- Substrate composition (preferably measured and not visually estimated)
- Stream shading
- Average water depth
- Stream gradient

Data storage

Data should be recorded on rain-proof field data sheets. All data sheets should be reviewed by the team leader before leaving a site to ensure all fields have been entered properly. Avoid carrying multiple completed field data sheets between sites as this increases the potential for data loss. Once the data from the field data sheets have been electronically entered, the sheets should be filed appropriately.

Forward copies of completed survey sheets to the survey administrator, or enter data into an appropriate spreadsheet as soon as possible. Collate, consolidate and store survey information securely, also as soon as possible, and preferably immediately on return from the field. The key steps here are data entry, storage and maintenance for later analysis, followed by copying and data backup for security.

Summarise the results in an electronic spreadsheet or equivalent. Arrange data as 'column variables'—i.e. arrange data from each field on the data sheet (date, time, location, plot designation, number seen, identity, etc.) in columns, with each row representing the occasion on which a given survey plot was sampled.

If data storage is designed well at the outset, it will make the job of analysis and interpretation much easier. Before storing data, check for missing information and errors, and ensure metadata are recorded.

Summaries of all fish survey data should also be entered into the New Zealand Freshwater Fish Database (NZFFD) administered by the National Institute of Water and Atmospheric Research (NIWA). The NZFFD is an important national repository for presence/absence data and represents a valuable resource for a range of different applications including research, impact assessments and threatened species monitoring. As a minimum, site location, fishing method and species collected should be recorded in the database forms. Data can be entered electronically using the Freshwater Fish Database Assistant software, which is freely available from the NIWA website.[2]

Storage tools can be either manual or electronic systems (or both, preferably). They will usually be summary sheets, other physical filing systems, or electronic spreadsheets and databases. Use appropriate file formats such as .xls, .txt, .dbf or specific analysis software formats. Copy and/or backup all data, whether electronic, data sheets, metadata or site access descriptions, preferably offline if the primary storage location is part of a networked system. Store the copy at a separate location for security purposes.

Analysis, interpretation and reporting

Seek statistical advice from a biometrician or suitably experienced person prior to undertaking any analysis. Statistical advice should preferably be sought during the design stage of any proposed monitoring programme. This is particularly important for the multi-pass method because the models used to calculate density estimates may need to be complex.

The primary reason multi-pass electrofishing is used is to generate density estimates for species of interest. This is achieved using removal or depletion models to estimate abundance based on the rate of reduction in fish numbers observed over consecutive passes. The selection of which removal model to use is complex and simple models such as the traditional 'Zippen' method can produce imprecise abundance estimates (Hayes et al. 2007). It is recommended that models which can test the key underlying assumptions around catch efficiency be used so the precision of abundance estimates can be assessed (Peterson et al. 2004; Hayes et al. 2007).

CPUE can also be derived from the first pass of multi-pass electrofishing and used as an index of relative abundance. However, if CPUE data are all that are required, it is strongly recommended that the fixed-reach method be used to sample fish, given the extra effort required to undertake multiple passes at a site and greater risk of injury to fish. CPUE data can be readily used to assess

[2] http://www.niwa.co.nz/our-services/databases/freshwater-fish-database

changes in relative abundances at a site over time provided that all sampling events occur under similar environmental conditions. It is therefore important to repeat sampling at the same time of year and avoid extreme flow conditions that may influence catch efficiency. Caution should be used when making comparisons of CPUE between sites as the assumption that the catch efficiency remains constant is likely to be violated in many situations. If between-site comparisons are made, it is important to be mindful of differences in variables that affect catch efficiency such as electrical conductivity and habitat complexity.

Depending on the objectives of the survey, it may be useful to assess population structure using any fish length data that have been collected. Length data are typically used to generate length-frequency histograms, which allow the structure of a fish population to be assessed. Length-frequency histograms can provide an insight into factors that may be affecting fish population dynamics, such as high mortality or recruitment failure (Anderson & Neumann 1996). When interpreting length-frequency histograms, it is important to consider potential size biases in sampling and whether sample size is adequate. Many statisticians now recommend density plots as an alternative to histograms because the selection of length category boundaries (i.e. minimum and maximum values) can have a large influence on the appearance of histograms.

Survey results should be reported on in a timely manner to ensure that they are available for future users. Extending the time between data collection and reporting increases the potential for useful information collected during sampling to be forgotten and lost.

Case study A

Case study A: Non-migratory galaxiid monitoring

Synopsis

This case study shows how the backpack electrofishing multi-pass method was used to monitor ‘Nationally Vulnerable’ Clutha flathead galaxias (*Galaxias* ‘species D’) in an Otago stream. Clutha flathead galaxias were monitored in a number of several small streams in the Clutha River catchment by the Coastal Otago and Wānaka Area Office staff. Data on fish populations and habitat were collected between 2005 and 2010 to meet various objectives set out in the New Zealand Non-migratory Galaxiid Fishes Recovery Plan (DOC 2004) and to guide future management of the species on the conservation estate. This case study focuses on part of the monitoring that was undertaken in one of the streams. More information can be found in the full monitoring report (Jack 2010).

Objectives

- To monitor the status of the Clutha Flathead galaxias population in Schoolhouse Creek.

Sampling design and methods

Two sites on Schoolhouse Creek were annually monitored from 2005 to 2010. All sampling was carried out over the April–May period each year. The Top and Middle sites were both located above a natural barrier that excluded brown trout (*Salmo trutta*). A third site downstream of the barrier was not included in the long-term monitoring because Clutha flathead galaxias had become absent there. A multi-pass electrofishing method developed by Allibone (1999) was used to collect Clutha flathead galaxias from a 50 m long reach at each site.

Data collection

- Electrical conductivity was measured prior to fishing and electrofishing machine voltage settings were adjusted to consistently produce 0.3 amps of current. A pulse frequency of 100 Hz and pulse width of 1 ms were always used.
- Each site was repeatedly electrofished in a downstream manner until the number of fish caught per pass fell below 25% of that caught in the first pass.
- Clutha flathead galaxias were counted and measured during each fishing pass.
- Five equidistant stream widths were measured and used to estimate the total wetted area of stream that was fished at each site.

Results

Fish abundance was estimated using a weighted maximum likelihood depletion model (Carle & Strub 1978). Changes in estimated fish abundances at Schoolhouse Creek observed between 2005 and 2010 are illustrated in Fig. 1. Estimates of fish density were then calculated based on the wetted area of the stream at each site (Fig. 2). The catch data collected from both sites in 2009 failed to meet the assumptions of the depletion model equation and an estimate could not be calculated. The proportion of juveniles (length < 55 mm) to adults in samples was also calculated to assess changes in recruitment patterns.

The density of Clutha flathead galaxias was found to fluctuate from year to year at both the Top and Middle sites in Schoolhouse Creek. The steep energetic character of the catchment was identified as the main factor driving the observed density fluctuations. Changes in density were not consistent across both sites, which suggests that site-specific factors are also involved. The proportion of juvenile fish in the population also fluctuated, especially at the Middle Site. Except for in 2008, densities of Clutha flathead galaxias were always higher in the Top site.

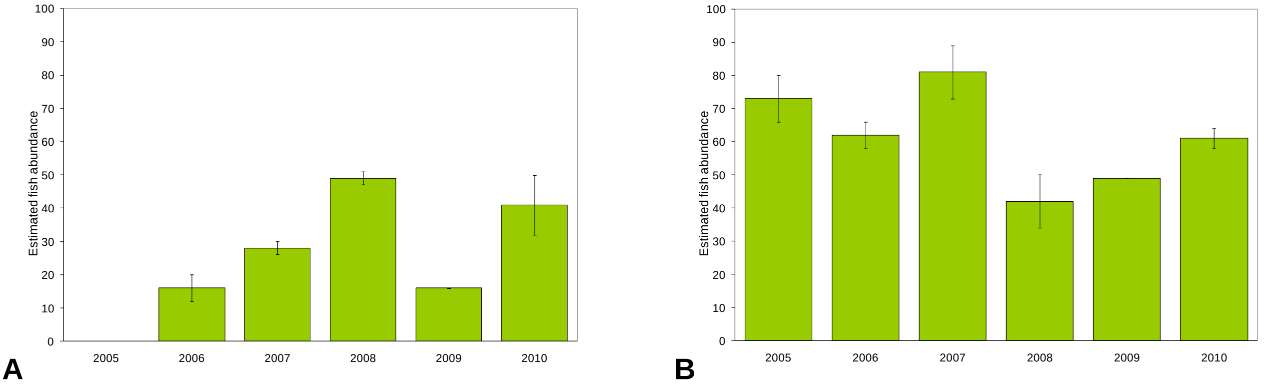

Figure 1. The estimated abundance (±95% confidence limits) of Clutha flathead galaxias in the Middle (A) and Top (B) monitoring sites, Schoolhouse Creek, 2005–2010.

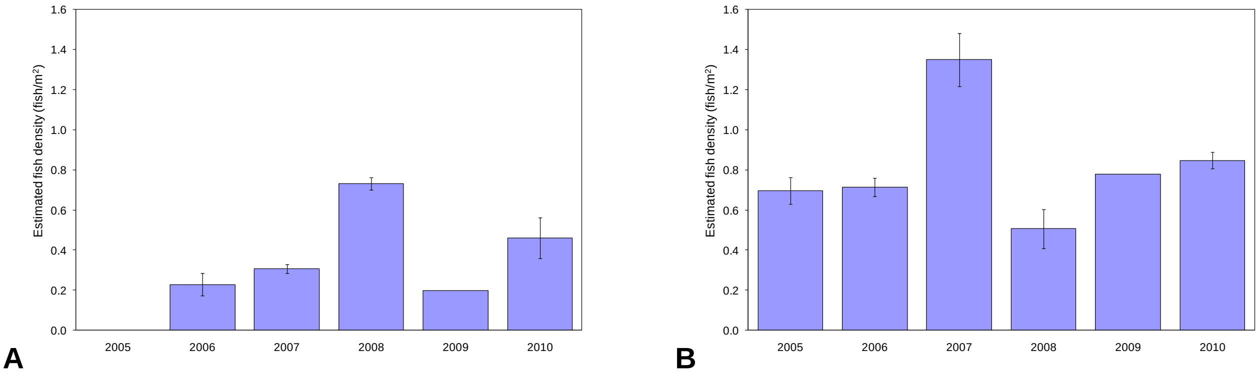

Figure 2. The estimated density (fish/m^2) of Clutha flathead galaxias in the Middle (A) and Top (B) monitoring sites, Schoolhouse Creek, 2005–2010.

Limitations and points to consider

- Although density varied from year to year, the population of Clutha flathead galaxias in Schoolhouse Creek was considered to be relatively stable. Annual monitoring of the Top and Middle sites was no longer considered necessary and ceased after 2010.
- Monitoring of the downstream barrier continued because of its importance in excluding brown trout from the upstream habitats.
- The assumption that capture efficiency does not change between passes has not yet been tested. It is therefore unknown how well estimated densities reflect true population densities present at each site. One future option could be to validate the multi-pass density estimates by testing capture efficiency using mark-recapture methods (Peterson et al. 2004). Any corrections could then be applied to the entire dataset.

References for case study A

Allibone, R.M. 1999: Monitoring strategy for the non-migratory Otago galaxias. NIWA Client Report DOC90227. 23 p.

Carle, F.L.; Strub, M.R. 1978: A new method for estimating population size from removal data. *Biometrics 34*.

DOC (Department of Conservation). 2004: *New Zealand non-migratory galaxiid fishes recovery plan, 2003–2013*. Department of Conservation, Wellington. 45 p.

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Peterson, J.T.; Thurow, R.F.; Guzevich, J.W. 2004: An evaluation of multipass electrofishing for estimating the abundance of stream-dwelling salmonids. *Transactions of the American Fisheries Society 133*: 462–475.

Full details of technique and best practice

The method described below is based on that developed for the monitoring of non-migratory galaxiids (Allibone 1999) and monitoring of salmonids in the USA (Temple & Pearsons 2007).

1. Select the stream reach to be sampled. The reach length sampled will be determined to a degree by the objectives of the study and the characteristics of the stream. Sample reaches in multi-pass electrofishing tend to be less than 50 m long due to the length of time it takes to complete multiple passes.
2. Place stop nets at the top and bottom of the sample reach. These are used to minimise the movement of fish into or out of the sample reach during fishing. A third stop net can be used to partition the sample reach into separate habitat types if this information is required. The mesh size of the stop nets must be small enough to exclude the smallest fish that are of interest to the study.
3. Record electrical conductivity and water temperature on the field sheet. If machine settings (voltage, pulse width and pulse frequency) have not already been determined in previous surveys or as part of a wider monitoring programme, then select the appropriate settings using the following guidelines:
   - Set voltage based on electrical conductivity: 100–400 V for high conductivity (> 300 µS/cm); 200–500 V for medium conductivity (100–300 µS/cm); 300–600 V for low conductivity (< 100 µS/cm).
   - Where mostly small fish are expected (most cases in New Zealand streams) use a pulse frequency of 60–70 Hz and pulse width of 2 ms. If larger fish > 200 mm are expected, use a pulse frequency of 30 Hz.
4. Run through pre-operational safety checks and then test settings in a section of stream *below* the sample reach. If six or more lights are showing on the wand, reduce the voltage until five lights or less appear (be aware that the number of lights showing will vary depending on how close together the two fishing electrodes are). If fish response is poor, increase the pulse width before increasing the voltage. Increase pulse frequency last to minimise mortality or injury of

large fish. If injuries or mortality occur, first decrease pulse frequency, then voltage, then pulse width.

5. Prior to initiating electrofishing reset the ‘elapsed time’ counter, record the start time and note down the GPS coordinates for the start of the reach.
6. Start backpack electrofishing. The machine operator starts on the edge of either bank and should be positioned 2–3 m upstream of the pole netter but closer if water velocity is low. The pole netter sets the pole net flush with the bed of the stream and perpendicular to the flow. The machine operator then sweeps the anode ring in a downstream direction and from side to side but always in line with the pole net. In this way a ‘lane’ of stream is sampled. The cathode or earth strap should be kept upstream of the pole net within the lane being fished or occupying area that has already been fished to avoid disturbing an unfished area. In flowing habitats, stunned fish within the lane will tend to be swept into the pole net but a dip net can be used to gently dislodge fish caught between rocks. The machine operator and/or third team member should collect other stunned fish as they are spotted using dip nets.
7. If slow-flowing pool habitat is being targeted, the pole net becomes less effective and most fish will be caught in dip nets held by the operator or assistants. When fishing undercut banks or log jams, fish can be drawn out by inserting the uncharged anode, switching it on and then pulling the anode out and away. Creating currents using the anode ring or dip-nets can often assist with pulling stunned fish out of complex structure when using this technique.
8. Transfer fish to live wells where they can be held until completion of all electrofishing passes. Placing a cover over live wells is advisable as some species of galaxiids are strong jumpers and this can also decrease fish stress by creating shade. Deep plastic buckets can be used as live wells and are easily transportable. When fish may need to be held for long periods of time, particularly during warm conditions, it will be necessary to regularly change the water and run a battery-powered aerator to maintain water quality.
9. Once a lane has been fished, move across the stream to an unfished lane and repeat the process. When the opposite bank is reached, both the machine operator and pole netter move upstream or downstream 2–3 m and begin fishing again. Electrofishing is normally carried out in an upstream direction but some operators working with non-diadromous galaxiids find fishing in downstream direction more effective provided the substrate is not too fine and easily disturbed. Continue fishing until the entire sample reach has been systematically fished.
10. Repeat steps 6–8 until the required number of passes have been completed. The number of passes required will depend on the removal model being used. However, a minimum of three passes is generally recommended. Allibone (1999) states that two sweeps are sufficient if the second catch is < 10% of the first, and if catches have not declined in the first three sweeps then additional passes are required until catches are < 25% of that in the initial pass.
11. Once the required number of fishing passes has been completed, release all non-pest fish species and retrieve stop nets.

References and further reading

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Temple, G.M.; Pearsons, T.N. 2007: Electrofishing: backpack and drift boat. In Johnson, D.H.; Shrier, B.M.; O'Neal, J.S.; Knutzen, J.A.; Augerot, X.; O'Neil, T.A.; Pearsons, T.N. (Eds): Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society in association with State of the Salmon. 478 p.

Appendix A

The following Department of Conservation documents are referred to in this method:

docdm-755847	Freshwater fish: electrofishing—fixed reach
docdm-676678	Electric fishing: one page SOP
docdm-752861	Electric fishing technical document—health and safety
docdm-870579	A guideline to monitoring populations
docdm-146272	Standard inventory and monitoring project plan
olddm-566603	Wading safely