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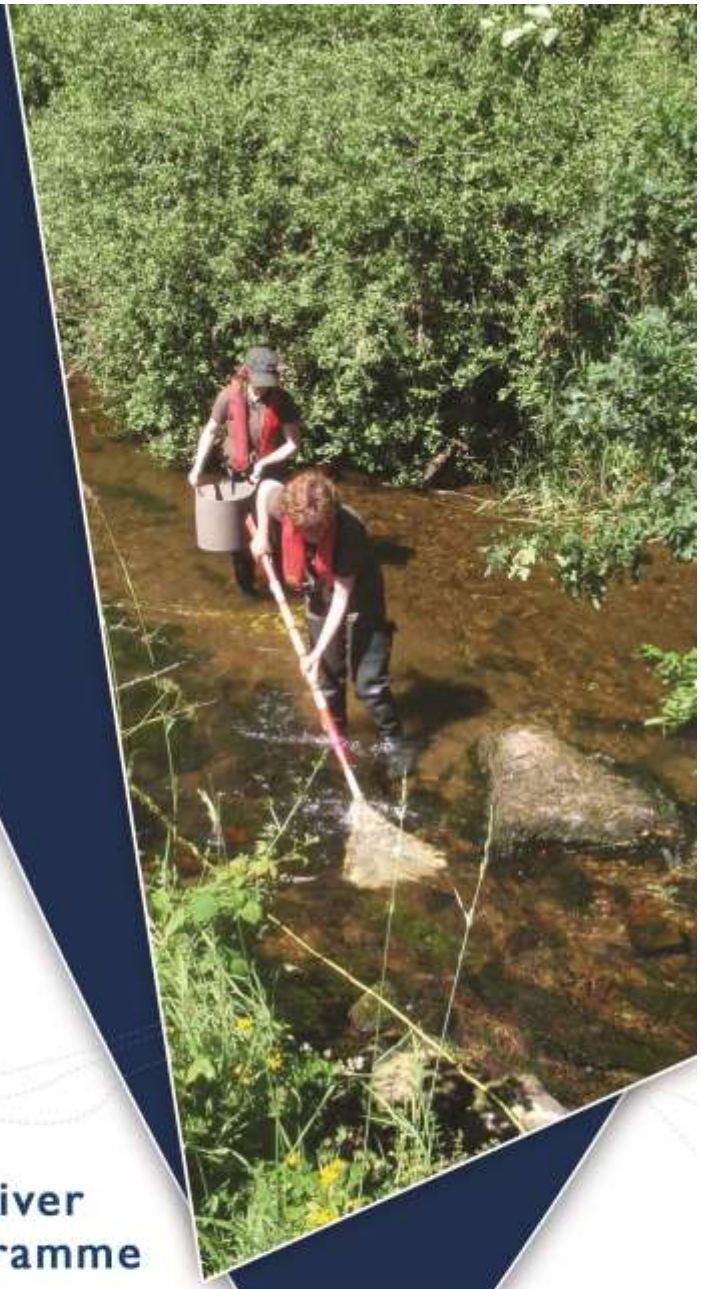

Environmental River Enhancement Programme Field Survey Methodologies

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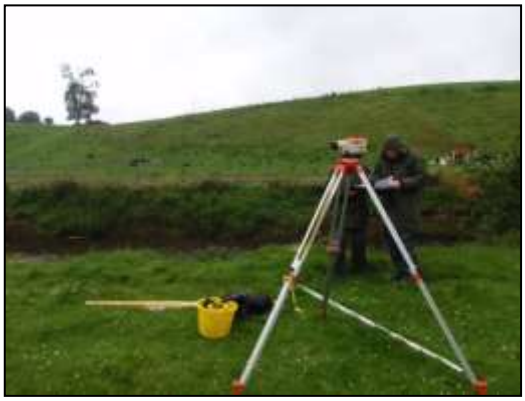
IASCACH INTIRE EIREANN
INLAND FISHERIES IRELAND

Environmental River Enhancement Programme (EREP)

Field Survey Methodologies



Iascach Intíre Éireann
Inland Fisheries Ireland

OPW
The Office of Public Works
Oifig na nOibreacha Poiblí

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1. INTRODUCTION

In 2008 the OPW commissioned Inland Fisheries Ireland (formerly the Central Fisheries Board) to carry out a study on routine and experimental methods of channel maintenance and enhancement and their environmental impacts with particular reference to fish, flora and stream morphology. This project was termed the Environmental River Enhancement Program (EREP).

The key objective of the EREP project is to undertake enhancement works within OPW drained channels and to monitor the impacts of such works on the river corridor biodiversity and hydromorphology.

The following are the areas of interest for environmental monitoring within EREP -

River Biodiversity

- Fish
- Flora (Plants & trees)
- Birds
- Macro-invertebrates
- Crayfish
- Lamprey

Hydromorphology

- Physical channel measurements
- Cross-sections / Longitudinal section

To monitor the impacts of maintenance and capital works programmes pre and post monitoring surveys were carried out on a selected number of channels. Pre monitoring tells us what the river biodiversity and hydromorphology is like before any maintenance/enhancement is carried out. Post maintenance allows us to see what changes have occurred and how river biodiversity and hydromorphology have altered post maintenance/enhancement

- ie have we lost certain species (flora, fauna) or gained new ones, how has the habitat changed, how has the channel profile has been altered,

- or by monitoring for several years after the works have been completed then we can follow the changes over a number of years and see if the diversity pre works will eventually return to the post works level and how long this many take.

In some instances baseline surveys were conducted which provided general information from a selected channel or catchment.

2. FIELD SURVEY METHODOLOGIES SUMMARY

2.1 EREP Fish Surveys

While the principal emphasis, within EREP fish stock surveys, is on brown trout and salmon, data is collected from all species encountered. Data collected will provide information concerning population estimates (nos/m^2), length frequency distributions, age structure and growth patterns. An assessment of the occurrence, population size and structure of all other fish species is also required.

Choice of electrofishing equipment, used to assess fish stocks in rivers, varied depending on the wetted width of the channel and its depth. In general, shallow wadeable waters were sampled using bank-based electrofishing equipment. Deeper channels required the use of small flat bottomed boats and suitable electrofishing equipment. A third option was also available, back-pack electrofishers, which were used mainly to 'spot fish'.

In order to assess the impacts of Enhanced Maintenance and Capital Works undertaken within OPW drained rivers, in terms of biological diversity, there was a need to establish the 'status quo', in fish terms, prior to any works being undertaken. However fisheries information for some OPW catchments is limited, especially in some of the more low gradient channels that would not be recognised as important salmonid systems. This lack of fisheries information at a catchment level has led to 10 minute Fish Population Index (FPI) electrofishing surveying protocol being initiated in 2009 and 2010. It is a preliminary survey method used to assess other OPW catchments into the future where fisheries information is not available or limited. However, electrofishing methods previously described were still used, and will continue to be used, where experimental and control monitoring sites are set up.

The FPI surveying technique quickly and efficiently increases fisheries knowledge in catchments where little or no recent data is available. The abundance level of certain fish species can also be used to infer water quality and the identification of imbalances in the population structure of certain fish species can be used to recognise habitat deficiencies. These surveys will also be used to identify crayfish and lamprey locations at a catchment level.

2.2 EREP Botanical Surveys

Collectively, the three vegetation 'types' that contribute to a properly functioning river corridor are the aquatic (in-channel), the marginal and the riparian plants. Given this, any survey methodology

must sample all vegetation types to get a representative record of the flora of the river corridor. Sampling of the control and experimental area is conducted before and after treatment allowing changes recorded to be compared within and between sites. The botanical survey programme used involved a semi quantitative sampling approach to most sites and a detailed quantitative study of selected experimental sites. Qualitative surveys were also undertaken at certain sites. Tree surveys were also carried out in which a species list and record of composition and abundance of tree cover in the site is compiled together with a general record of the age/size structure.

2.3 EREP Bird Surveys

Birds can be a very significant element in the biodiversity of a river corridor and those present are likely to be impacted by OPW drainage maintenance or indeed to any disturbance within the river ecosystem.

In general, standard bird survey methods used by Bird Watch Ireland and other relevant agencies were applied. Some minor adjustments were made to the standard recording forms, to fit the project requirements. In order to accurately reflect both the migratory and resident populations in Ireland, a two stage sampling programme was undertaken. The first of the two visits conducted at each waterway, was undertaken from mid April to mid May. This reflects the abundance of residents and early migrants observed in Irish waterways. The second survey from mid May to mid June, reflects the later migrants in waterways. A minimum period of four weeks was left between the two surveys. It is important that both sampling periods, and all subsequent surveys to a site, were undertaken by the same observers where possible, to minimise the likelihood of error.

In 2010 the bird survey programme was expanded to include control sites in non-drained channels. This was undertaken firstly to determine if there are significant differences in the abundance and distribution of waterway bird species in drained versus non-drained channels. And secondly to examine the natural population fluctuations within channels which have no arterial drainage.

Also in 2010 an ‘Additional Bird Sightings’ database was established. This database recorded all bird species observed in the river corridor by the EREP team outside formal surveys. This was similar to the roving records sampling programme adopted by Bird Watch and involved recording all bird species observed in the river corridor, together with associated GPS location and date.

2.4 EREP Macro-invertebrate Surveys

The macro-invertebrate community of a river responds quickly to change and so it is a good reflection of conditions in the short-term. Invertebrate assemblages reflect changes in habitat as well as changes in water quality as most species have preferences for either fast or slow flowing water, sheltered or exposed areas, silt or cobbles. The objective of this study is to adequately assess changes in the aquatic macro-invertebrate community following execution of capital enhancement works. Incorporated within this objective is the requirement to describe the biodiversity of the macro-invertebrate community.

As with all other aspects of the EREP project there is a need to provide a species inventory list for OPW channels. The development of the aquatic macro-invertebrates species inventory will be an ongoing task that will be built upon over the life of the EREP study. This programme also involves monitoring the impacts of enhancement works, pre- and post development within a selected number of channels, on the macro-invertebrates. Again this monitoring involves sampling both experimental and control sites. The method involved taking a multi-habitat sample i.e. pool, riffle and glide habitats are sampled at the same time. All samples were identified to the lowest taxonomic level suitable for water quality assessment, in accordance with EPA guidelines. Following identification, taxa was allocated to their functional feeding group. This complimented the biodiversity taxonomic listing and showed changes in community composition that may be a reflection of the OPW's instream works e.g. removal of stone material and vegetation may reduce the number of shredders and grazers present in a site.

2.5 EREP Crayfish Surveys

Crayfish in Ireland are represented by a single species, *Austropotamobius pallipes*, commonly known as the white-clawed crayfish. As the white-clawed crayfish is listed under the EU Habitats Directive as an Annex II species, it is imperative to monitor the effects of maintenance on crayfish populations in OPW drained channels and to mitigate any potential maintenance impacts. In order to comply with the Wildlife Acts 1976 to 2010, all staff surveying white-clawed crayfish under EREP must obtain a license to 'capture wild mammals for educational, scientific or other purposes' from the National Parks and Wildlife Service. Crayfish surveys are avoided from October to late June so as to avoid sampling the population when females are 'in-berry' and to avoid the winter months when the crayfish tend to be less active. In order to prevent the spread of invasive species such as the crayfish plague, all equipment used was frozen and/or treated with a Virkon Aquatic solution.

Sampling methods for crayfish include the use of regular fyke nets, mini fyke nets, crayfish traps, electrofishing, hand-grabbing and spoil and vegetation sampling using tarpaulin. The type of method used will depend on a variety of factors such as channel depth, vegetation type, time of year and whether the adult and/or juvenile crayfish populations are being assessed. Techniques such as spoil sampling and electrofishing tend to capture a greater size range of crayfish, than methods such as fyke netting and traps, due to the fact that juvenile crayfish can escape the meshing in these.

2.6 EREP Lamprey Surveys

There are three species of lamprey found in Ireland, river lamprey (*Lampetra fluviatilis*) brook lamprey (*Lampetra planeri*), and *Petromyzon marinus* commonly known as sea lamprey. Similar to white-clawed crayfish, all three of the lamprey species are listed as Annex II species under the EU Habitats Directive. Their inclusion in the directive requires that member states allow areas to be designated as Special Areas of Conservation (SAC), which in turn has legal implications for the OPW maintenance and capital works programmes. As a result it is imperative to monitor the effects of maintenance on lamprey populations in OPW drained channels and to mitigate any potential maintenance impacts.

Sampling methods utilized for this study depended on factors such as channel depth and include the use of 1 meter squared mesh enclosures, qualitative spoil sampling, quantitative spoil sampling using tarpaulin, electrofishing and sweep net sampling.

2.7 EREP Physical Surveys

This type of sampling involves taking a series of measurements which represent channel dimensions, throughout the selected sites, including all replicates. Variables to be measured include bank-full width, wetted width, channel length, depth, velocity and canopy cover. These measurements will be taken annually, initially, at those sites where alteration or changes in these dimensions are likely to occur as a result of enhancement or of maintenance works. Transects are uniformly spaced, at 5 - 10m intervals, depending on channel size and length of replicate site. Each of these measurements should be taken at right angle transects from left hand bank to (LHB) to right hand bank (RHB).

Longitudinal and cross sectional surveys of a channel under investigation are undertaken using a theodolite or levelling telescope and 5m telescopic survey staff and surveying was conducted using standard engineering practices.

Velocity is measured using a portable flowmeter (electromagnetic). 14 width/depth/velocity measurements are taken in the cross sectional transect of any specified channel. The number of readings taken permits a calculation of 'Q' or volume discharge.

Depth is measured, at transects of 5m intervals. 5 readings are taken (evenly spaced) across the transect in the wetted width and 2 more, 1 at each margin within 0.05m of the wetted edge.

Canopy cover, also known as, crown closure, crown cover, or canopy closure, is defined as the percent of canopy overlying the forest floor / river bed. Canopy cover/closure is measured to the nearest percent using a concave spherical densiometer. The canopy cover readings are taken 30cm off the waters surface. Shading from tall marginal plants, as well as from woody canopy, may also be taken into account.

3. DETAILED FIELD SURVEY TECHNIQUES

3.1 Fish Survey Methodologies

A selection of paired sites should be chosen for each treatment:

- Control - in which no manipulation is done.
- Experimental which is treated in a pre-determined manner.
- A third treatment is possible, i.e. standard maintenance, when length of channel is available.
- Each site must be representative of the river as a whole and if a physical feature of the channel is being measures (e.g. berms, tunnelling) it must be uniformly present throughout the 5 replicates within the site.
- If sites are being compared (e.g. Tunnelled, open) optimally, a similar base width and volume discharge should be present at each site.

Monitoring is carried out prior to treatment. In each case every attempt is made to ensure that paired or triplet sites are as similar as possible in physical and ecological terms. Post-monitoring is carried out at 12 monthly intervals at the same time of year and with similar water levels. Water temperature is an important parameter which should be measured at every opportunity during the survey (a number of times daily).

The principal emphasis in the EREP fish stock survey is on brown trout and salmon. This requires:

1) Population density estimates (No/m^2) (Population density estimates for 0+, 1+ and >1+ fish to be carried out separately).
2) Length frequency distribution
3) Set of scales for aging (range of sizes needed)
4) Growth rate curve

As population estimates are not calculated for non salmonid species an abundance rating is presented. This system scores fish abundance 1 – 5 scale (1= 1-10 fish, 2= 11-50 fish, 3= 51-100 fish, 4= 101-200 fish, 5= >200 fish).

Sites are electrofished to establish species distribution, population size, density, biomass, age structure and growth of fish and to quantify the effects, if any, of experimental maintenance work.
In small, shallow channels a portable landing net (hand setting) connected to a control box and portable generator (bank-based) is used to electrofish in an upstream direction. In larger channels, fishing is carried out from a flat-bottomed boat using a generator, control box and paired poles. Boat fishing is carried out in a downstream direction. In low conductivity rivers an adaptation of the two methods is used, electrofishing being carried out from a flat bottomed boat using a handset generator, control box, poles and plates (handsetting) in a downstream direction. The sampling area should be isolated using stopnets or be clearly delineated by instream hydraulic or physical breakpoints such as shallow riffles or weirs.
The 10 minute FPI survey is designed to create a fish population index which allows for greater spatial coverage across a given catchment in a shorter period of time. In wadeable rivers (water depth <50cm) a suitable site is located, which should cover a riffle-glide-pool sequence, if present, and bank side electrofishing equipment is used. The site is then fished for a period of exactly 10 minutes. This on average corresponds to a channel length of approximately 20-30m depending on channel width. In deeper river channels (water depth >50cm) boat based equipment is used. Here the boat is rowed down the channel and the site is then fished for a period of exactly 10 minutes. This corresponds to approximately 150 – 400 meters in channel length.

The same method should be used in each sampling period (for statistical comparison). Cases I to IV specify (on data sheets): method used and surface area of site (length*mean width).

I. Minimum density – 1 fishing only
II. Depletion – 2/3 fishings.
III. Mark-recapture

IV. 10 minute Fish Population Index (FPI) survey

Minimum density (1 fishing):

This is adequate in an area of very low fish stock or very low numbers of target species PROVIDED fishing is effective and gear in proper order. Divide numbers caught by the surface area (Crisp *et al*., 1974).

Depletion:

- Gives much detail in a small area.
- Upstream and downstream ends should be clearly delineated by hydraulic/instream habitat jumps/obstacles or stop nets.
- Install stop nets as first requirement before setting up any other gear
- 3 fishings are required (if 2^{nd} fishing > 25% of 1^{st} ie. If poor depletion). 3 fishings can give very tight confidence intervals. The same fishing effort must be used in each removal pass. To allow time for 'recovery ' of non-captured fish still instream , process captured fish from the'i'th fishing before doing the 'j'th fishing.
- Use Seber and LeCren (1967) for 2 fishings only.
- Use Zippin (1956) for 3 fishings, BUT use Carle and Strub (1978) if Zippin gives spurious results. IF all else fails, combine numbers from all fishings and get minimum density estimate.

Mark-recapture:

- Ideal for long segments(>200m)
- Fish as series of sub-segments, each of which displays a uniformity of character and ideally, has its own hydraulic barriers/break points at u/s and d/s ends
- Ideal for long segments with few fish – provides numbers for length-frequency distributions. Useful in Urban flood relief studies.
- Provides population estimate in cases when inadequate coverage of electric field occurs.
- Use the following formula (Bailey, 1951):

  $a(b + 1)/(c + 1)$

  a = No. marked, b = total recaptured and c = no. marked in recapture.

10 minute Fish Population Index (FPI) survey:

- Allows larger number of sites per day to be surveyed
- Fished in similar sites to "Depletion" fishing but without stop nets and for exactly 10 minutes

- Greater special coverage in a catchment wide survey

The removal/depletion and mark-recapture methods are the most widely used techniques. Fish from each pass are sorted and processed separately. All fish are measured for fork length within 1cm length groupings. Scales of salmon and trout are taken from a representative range of sizes for back-calculation of length-at-age and examination of growth pattern. All fish are held in a large bin of water after processing until they are fully recovered and then returned to the water.

3.2 Botanical Survey Methodologies

Collectively, the three vegetation 'types' that contribute to a properly functioning river corridor are aquatic (in channel), marginal and riparian. Together, they play an important role in maintaining suitable habitat for invertebrates, fish, mammals and individual plant species. They provide shade and cover, breathing areas for fauna, promotes bank stability, enhance physical channel features, filter sediment, oxygenate water and serve as a major source of nutrients to support fauna and flora. Enhancement/maintenance projects are intended to maintain or improve one or more of these functions.

The time period over which vegetation responds to enhancement/maintenance depends on the plant community type (aquatic, marginal, herbaceous, shrub and trees) and the functions targeted for enhancement/maintenance. In the initial phases of monitoring (1-2 years after implementation), it may only be possible to assess whether or not vegetation was successfully established on a site or alternatively, if nuisance species have been removed or controlled. Subsequent monitoring will focus on the development of community characteristics such as species diversity or canopy cover. Over the long term, the focus may shift to other conditions such as stream temperature or habitat diversity. As the emphasis changes from the vegetation to the functions of the vegetation, the methods used for monitoring will also change. During the initial phases, species counts and percentage cover records obtained with the use of repeatable field techniques should be adequate. These can be repeated later within a more complex sampling design to obtain statistically valid measurements of community characteristics if necessary.

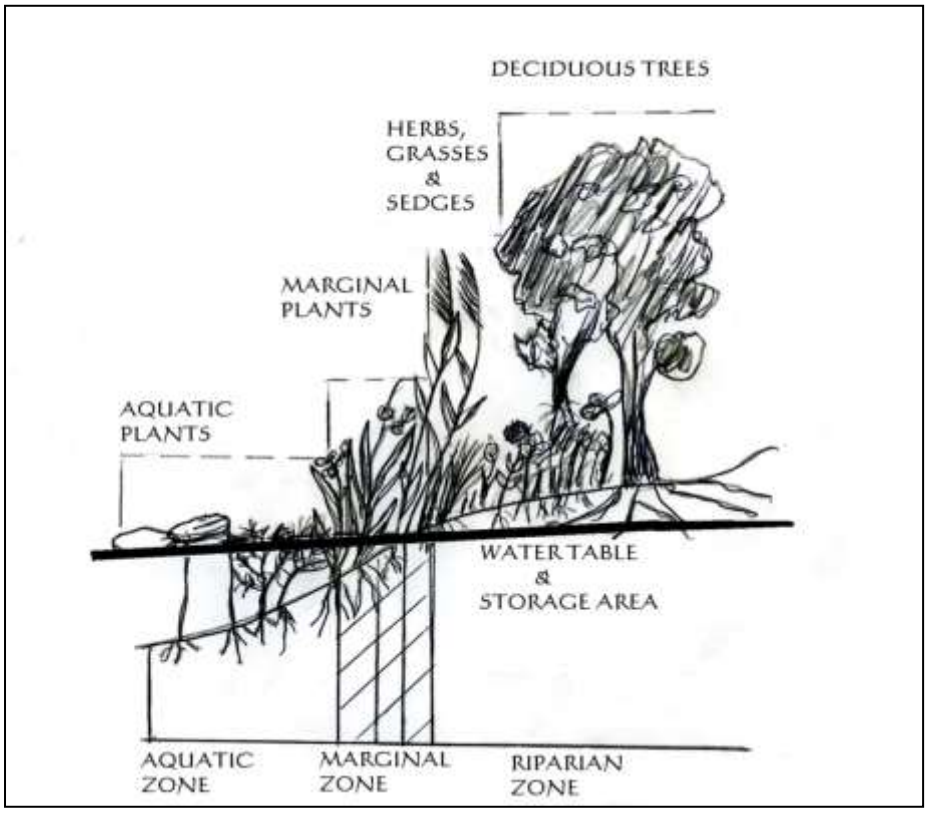


Figure 1: Illustration of the different vegetation types that occur in a healthy river corridor.

The general study design recommended here is a before-after-control-impact approach (BACI), (El-Shaarawi and Piegorsch 2002, Stewart-Oaten *et al*. 1986, Crawford and Johnson 2003). Sampling of the control and the impact area is conducted before and after treatment allowing changes to recorded and compared within and between sites.

The methodology requires that the three main vegetation/habitat 'types' found in the river corridor are surveyed i.e. the river channel, river bank and riparian zone. This will take three forms:

1. A record of species and a record of the vegetation structure using survey forms. The purpose of recording the vegetation structure is to provide information on the range of functional habitats that vegetation may be providing for invertebrates, fish and other animals. This is especially important in river corridors with otherwise limited structural diversity, as may be the case in arterial drained rivers.
2. A series of cross sectional quadrats. This technique will provide quantitative data that can be repeated to assess changes over time.
3. A tree survey.

METHOD 1

The methodology requires that the three main vegetation/habitat 'types' found in the river corridor are surveyed and monitored i.e. the river channel, river bank and the riparian area. This will take three forms:

The following information should also be recorded using survey forms -

I. The Bank face and Riparian Vegetation Structure

Vegetation structure is based on the four categories: Bare, Uniform, Simple and Complex.

II. River Channel and Marginal Vegetation types

Channel vegetation types will be assessed during a walkover survey of the site. Vegetation types are recorded in categories that assess the habitat structure they provide at the time of survey. The purpose is to provide information on the range of functional habitats that vegetation may be providing for fish, invertebrates and other animals. This is especially important in rivers with otherwise limited structural diversity.

The values for 'Channel Vegetation types' can be derived from scores for species in the 'River' records (either from relative abundance or actual abundance). It has the advantage that it can be done either in the field or back at base. To be recorded as present (P), a channel vegetation type need only to be observed on site. To be recorded as extensive (E), the channel vegetation type must occupy at least 33% of the channel area. Thus, vegetation growth should be obvious, and time should not be wasted looking for isolated plants. Several vegetation 'type' entries will be made for the same sample point when there is more than a single type present. Listed below are the Channel Vegetation types.

METHOD 2

I. A walkover survey of the entire sample site where all species encountered are recorded should be completed.

II. The survey at each site includes a series quadrats that aims to cover the entire channel and both bank sides i.e. a cross section. This should take place at fixed points (e.g. every 20m) over an area of 80-120m depending on the diversity of the site.

- At each fixed sampling point, quadrats will be taken for each of the three vegetation types (riparian, marginal and aquatic). For example, quadrats will be taken for the riparian/upper bank,

mid-bank, marginal area, in-channel, in shallow and deep areas where possible. This is repeated along the sample site e.g. every 20m, so that repeated sampling is possible in the future. Where no marginal or aquatic vegetation exists, no sample is taken.

Separate records are necessary for those species found in the river, on the bank and in the riparian zone. This is an attempt to distinguish between species that are more or less permanently submerged those that are periodically submergence and those that are true terrestrials. They will be referred to as 'river' records, 'marginal' records and 'riparian' records hereafter.

To make the separation of these records objective, the following guidelines will be observed (adapted from Holmes 1983 and 1999). In general terms, therefore, 'river' records are reserved for macrophytes occurring in the region of the river that is rarely uncovered, and shallow sections that have an upper limit that may be exposed for a maximum of 2 months in any year.

'Marginal' records are for plants that occur above the limit of the 'river' plants, and are may be out of the water for extended periods of the year, yet will be submerged, or partially so, during average flow periods and 'riparian' records are for plants which are inundated only during floods. Such estimates have to involve guesswork, but estimates of submergence levels do allow better interpretation of the data and clearer insights into the ecology of individual species and communities at different sites (Life in UK Rivers, 2003).

Survey results will be tabulated as follows: any species present within a quadrat (1m x 1m) is denoted by a score, either under River, Marginal or Riparian (note that in the case of marginal plants it is not uncommon for some of these species to be recorded across habitats.)

The score refers to absolute abundance or percentage cover and is a semi-objective assessment based on the percentage of the quadrat covered by each species. This based on the Braun-Blanquet method of botanical recording. Assessment is made using a modified Domin scale.

1 = 1-2 individuals. No measurable cover. Individuals with normal vigour
2 = several individuals but less than 1% cover
3 = 1-4% cover.
4 = 4-10% cover
5 = 11-20% cover

6 = 21-34% cover

7 = 35-50% cover

8 = 51-75% cover

9 = 76-90% cover

10 = 90-100% cover

METHOD 3

Tree Survey - The tree survey together with method 1 and 2 will provide a good picture of the vegetation structure and species present. In particular, it will compliment certain elements of method 1 i.e. the bank face and riparian vegetation structure and the extent of trees and associated features. Here, a species list and record of their abundance will be compiled together with a general record of the age/size structure. This will allow us to monitor changes in species abundance and stand structure over time. See appendix 2 for survey form.

For the purpose of the vegetation structure records, trees are recorded using the following categories.

For small tree species such as *Prunus spinosa, Crataegus monogyna* and *Salix cinerea*,

Young	1-3m
mature	4m +

For species that can grow to be large such as *Fraxinus excelsior, Alnus glutinosa, Salix alba* and *Acer pseudoplantanus*,

Young	1-4m
mature	4m +

IMPACT STUDIES.

A number of experimental sites are selected for a detailed investigation of the impacts of maintenance works on the plant flora. In 2010, experimental sites were surveyed by compiling a species list, a tree survey where necessary and a series of quadrats. The quadrats provide a quantitative record of the species list and degree of cover provided by each species and a series of quadrats is compiled in each trial plot. This facilitates a before- and after- statistical testing for changes in the flora following works. Two such impact studies were surveyed in 2010:

- A series of berms on the River Deel, Limerick were subject to different management strategies following quantitative sampling of the existent flora. A total of 36 1 x 1m quadrats were compiled across 4 berms. These will be monitored over the coming years to assess the impact of the different management approaches on plant recolonisation.

- A heavily wooded section (260m approx) of the Gageborough River had tree growth on both bank slopes. A set of 10 quadrats was compiled on each bank. The riparian understorey and trees were subject to a detailed quantitative survey. Clumps of trees at given intervals will be removed and the impact of this on the riparian, marginal and aquatic vegetation will monitored in the coming years.

3.3 Bird Survey Methodologies

Birds can be a very significant element in the biodiversity of a river corridor and those present are likely to be impacted by OPW drainage maintenance or indeed to any disturbance within the river ecosystem.

In general, standard bird survey methods used by Bird Watch Ireland and other relevant agencies were applied. Some minor adjustments were made to the standard recording forms, to fit the project requirements. In order to accurately reflect both the migratory and resident populations in Ireland, a two stage sampling programme was undertaken. The first of the two visits conducted at each waterway, was undertaken from mid April to mid May. This reflects the abundance of residents and early migrants observed in Irish waterways. The second survey from mid May to mid June, reflects the later migrants in waterways. A minimum period of four weeks was left between the two surveys. It is important that both sampling periods, and all subsequent surveys to a site, were undertaken by the same observers where possible, to minimise the likelihood of error. Each survey began shortly after dawn and finished at approximately 10am, to coincide with the period of greatest bird activity. Additionally, in order to facilitate accurate gathering of data, surveys were conducted only on days with relatively dry and calm weather conditions.

For the purpose of this survey a line transect method was utilized. It involved two observers standing on opposite banks, beginning at predefined starting points and walking 500m in a fixed line along the river bank in a slow steady pace, whilst recording all the adult birds seen or heard within relevant distant bands. The distance bands utilized left and right of the transect line are <5m, 5-10m,

10-15m, 15-20m, 20-25m and >25m. Each distance band reflects the perpendicular distance from the transect line to the individual bird recorded. The position of the river within the relevant distant bands was also recorded.

To facilitate accurate recordings of observed birds, each transect was further sub-divided into five 100m sections. Hand-held GPS instruments and maps were used to mark the start and end of each 100m section. Every effort was made to ensure that each bird was recorded in the 100m section they are first observed and that each bird is recorded only once. Birds not conclusively identified were omitted.

Data collected at each site was pooled into one survey sheet. Additionally behaviours such as nesting, aggression, feeding and bathing were also recorded by each observer. Birds in flight were recorded separately, although birds that are usually seen in flight, such as House Martins, Sand Martins and Swallows, which use the river habitat or the surrounding area, were recorded within the appropriate distant band. Additionally, birds which were seen outside the sampling transect, for instance behind the observer, were only recorded in the additional species section of the data sheet. Site variables were also recorded at each site - these include drainage history, width of channel, vegetation stratification profile and bank slope features. For the purpose of this survey the river corridor encompasses both the river and the bank full on both banks.

In 2010 the bird survey programme was expanded to include control sites in non-drained channels. This was undertaken firstly to determine if there are significant differences in the abundance and distribution of waterway bird species in drained versus non-drained channels. And secondly to examine the natural population fluctuations within channels which have no arterial drainage.

In 2010 in order to give a more accurate representation of species richness in both drained and non-drained channels, an 'Additional Bird Sightings' database was established. This database recorded all bird species observed in the river corridor by the EREP team outside formal surveys. This was similar to the roving records sampling programme adopted by Bird Watch and involved recording all bird species observed in the river corridor, together with associated GPS location and date.

3.4 Macro-invertebrate Survey Methodologies

The macroinvertebrate community of a river responds quickly to change and so is a good reflection of short-term conditions. Invertebrate assemblages reflect changes in habitat as well as changes in water quality as most species have preferences for either fast or slow flowing water, sheltered or

exposed areas, silt or cobbles. The objective of this study is to adequately assess changes in the aquatic macroinvertebrate community before and after improvement works. Incorporated within this objective is the requirement to describe the biodiversity of the macroinvertebrate community.

Methods

- Kick samples are taken using a 500micron mesh pond net.
- The operator will kick into the net, dislodging the upper surface of the river bed thoroughly while moving backwards upstream.
- Kicks are timed for 2.5minutes.
- Three habitat types will be sampled per site, pool, glide and riffle and each habitat type will be sampled three times to provide replication. However at some sampling sites, not all habitat types are present, in this case three replicates of the available habitats are sampled. Replicates should be taken from different location where possible, i.e. ideally three riffle samples should be taken from three separate riffles within the study site. Where a habitat is only found once within a study reach, it should be sampled three times to provide the three replicates.
- Each sample is stored separately in 70% ethanol until processing.
- When sorting samples, all macroinvertebrates are removed and identified to the lowest taxonomic level suitable for water quality assessment in accordance with EPA guidelines :

Platyhelminthes	genus	Trichoptera	genus
Oligochaeta	family	Ephemeroptera	genus
Hirudinea	genus	Plecoptera	genus
Mollusca	genus	Odonata	genus
Crustacea	family	Megaloptera	genus
Hemiptera	genus	Diptera	family
Coleoptera	family	Hydracarina	presence

3.5 Crayfish Survey Methodologies

Crayfish in Ireland are represented by a single species, *Austropotamobius pallipes*, commonly known as the white-clawed crayfish. As the white-clawed crayfish is listed under the EU Habitats Directive as an Annex II species, it is imperative to monitor the effects of maintenance on crayfish populations in OPW drained channels and to mitigate any potential maintenance impacts. In order to comply with the Wildlife Acts 1976 to 2010, all staff surveying white-clawed crayfish under EREP must obtain

a license to ‘capture wild mammals for educational, scientific or other purposes’ from the National Parks and Wildlife Service. All crayfish captured during the course of the EREP studies were sexed, had cheliped loss and moulting recorded and their carapaces measured using rulers or Vernier calipers and released back unharmed. Furthermore, information such as the presence of Porcelain disease, Burnt Orange disease, and whether the females were ‘in-berry’ were also collated. Crayfish surveys are avoided from October to late June so as to avoid sampling the population when females are ‘in-berry’ and to avoid the winter months when the crayfish tend to be less active. In order to prevent the spread of invasive species such as the crayfish plague, all equipment used was frozen and/or treated with a Virkon Aquatic solution.

Sampling methods for crayfish include the use of regular fyke nets, mini fyke nets, crayfish traps, electrofishing, hand-grabbing and spoil and vegetation sampling using tarpaulin. The type of method used will depend on a variety of factors such as channel depth, vegetation type, time of year and whether the adult and/or juvenile crayfish populations are being assessed. Techniques such as spoil sampling and electrofishing tend to capture a greater size range of crayfish, than methods such as fyke netting and traps, due to the fact that juvenile crayfish can escape the meshing in these.

Fyke nets are laid overnight in the channel, and as the predominantly nocturnal crayfish are foraging, they encounter the leader line and are funnelled into the mouth of the nets thus becoming trapped in the ‘cod end’. The choice of fyke net used is dependent on the depth of water in the channel. In deeper channels the round ‘Dutch’ type regular fyke nets are utilized. These nets are double ended funnel shaped traps and are joined in the centre by an 8m leader line. To ensure the leader remains in the correct position in the water column, it is mounted with plastic floats and sinkers. Each funnel shaped end comprises of seven rings, which taper off to a ‘cod end’ trap and the mesh size of the funnel is 17mm, 14mm and 11mm or 18mm, 17mm and 10mm. To prevent the capture of otters, the first ring of all regular fyke nets are fitted with ‘otters guards’. These 17cm x 17cm square guards are comprised of stainless steel and prevent the otter entering the open aperture at the first ring. Weights are also attached to each end of the net, and the net is set on the channel bed overnight. Mini fyke nets are generally used in shallow water channels as they are smaller in size. The diameter of the first ring is 40cm as opposed to that of the 55cm regular fyke net. Additionally the mini fyke nets comprise of 5 rings, with a funnel mesh size of 17mm, 14mm and 11mm.

Similar to fyke nets, the non-baited crayfish ‘Trappy’ traps are placed on the channel bed and left over night, to coincide with the period of maximum crayfish activity. These double mesh traps are

cylindrical polypropylene plastic tunnels, with two entrances, and are designed to trap crayfish by attracting them into a potential 'refuge'. The traps are weighted to ensure they remain on the channel bed, and are tied together in a series using rope, thus preventing the traps becoming lost in within the channel.

Spoil and vegetation sampling using tarpaulin is a quantitative method which is employed in union with OPW maintenance or capital works programmes. By measuring the diameters of the machine bucket, a known surface area of spoil and/or vegetation is excavated and placed on a tarpaulin. Once on the tarpaulin the spoil and/or vegetation are inspected by the EREP staff, thus allowing the minimum population density of crayfish to be calculated. This survey can give invaluable insights into the potential impacts OPW works can have on a channel, and also which substrate and vegetation type's crayfish utilize, thus having in the implications for instream vegetation and substrate management. Additionally qualitative spoil sampling can be undertaken to determine the presence/absence of crayfish an area of channel. This involves investigating the spoil placed on the bank immediately post OPW maintenance, and collecting any crayfish found for processing.

In shallow wadeable channels electrofishing has also been deployed, using bank based or back-pack electrofishing equipment. Deeper channels were fished using boats and boat based electrofishing equipment. As with the fish sampling methodologies, quantitative electrofishing methods were always employed, with the exception of the 10 minute Fish Population Index (FPI). Both the quantitative and qualitative surveys not only give measurements of presence/absence and length-frequency distribution, but they also give an indication of the effects of maintenance and capital works programmes on crayfish populations. Electrofishing ideally works in channels where there are a lot of crevices for crayfish to hide, such as cobbles and vegetation. The electrofishing works by passing a charge through the water, the crayfish are repelled by the cathode plate and attracted to the hand net which has a positive charge. However, crayfish can avoid capture by remaining stunned in these 'refuges'. Additionally, hand catching will also need to be incorporated into this survey if the stunned crayfish doesn't float down to the landing net.

Hand-grabbing was utilized as a method of assessing the presence or absence of crayfish at a site. Good water clarity and shallow wadeable water are two factors which are required for this survey. While standing downstream, the hand-grabber over turns cobbles and boulders in the channel and captures any crayfish beneath either by hand or using a net.

A sweep net method, using a hand-held kick sampling net was used in a number of channels. The area of the site was first measured and the sweep net was carried out for a fixed period of time within the site.

Surber samples are a quantitative sampling method, which consists of a rigid frame that is set on the channel bed, with a net that is attached to the downstream end. The substrate and vegetation within in the frame is disturbed for a fixed period of time using an object such as a trowel and the crayfish are collected in the attached net.

3.6 Lamprey Survey Methodologies

There are three species of lamprey found in Ireland, river lamprey (*Lampetra fluviatilis*) brook lamprey (*Lampetra planeri*), and *Petromyzon marinus* commonly known as sea lamprey. Similar to white-clawed crayfish, all three of the lamprey species are listed as Annex II species under the EU Habitats Directive. Their inclusion in the directive requires that member states allow areas to be designated as Special Areas of Conservation (SAC), which in turn has legal implications for the OPW maintenance and capital works programmes. As a result it is imperative to monitor the effects of maintenance on lamprey populations in OPW drained channels and to mitigate any potential maintenance impacts. All lamprey captured were anaesthetised using phenoxyethanol for processing. After processing they were transferred to fresh water 'recovery' buckets, and once fully revived were returned to the channel unharmed. During processing all lamprey were measured to the nearest millimetre and classified as ammocoetes, transformers or adults based upon the shape of the oral hood, the presence/absence of eyes and the shape of gills openings. Species were delineated based upon the pigmentation pattern of the horal hoods and caudal fins.

Sampling methods utilized for this study depended on factors such as channel depth and include the use of 1 meter squared mesh enclosures, qualitative spoil sampling, quantitative spoil sampling using tarpaulin, electrofishing and sweep net sampling.

The 1 meter square mesh enclosure is a quantitative electrofishing technique used in shallow wadeable channels of suitable sediment, which involves placing four metal poles, 1.1m in length into the channel at the four corners of a square. A fine mesh enclosure is then attached to these poles. Juvenile lamprey utilize silt and sand substrate for a nursery habitat, and electrofishing this enclosure allows the stunned ammocoetes to be captured. The electrofishing works by passing a charge through the water, the lamprey are repelled by the cathode plate and attracted to the hand

net which has a positive charge. The fishing is done using an on/off technique, whereby the enclosure is fished for 20 seconds followed by a 5 second break. This technique is repeated to allow for 120 seconds of fishing time. The 5 second down time allows the stunned ammocoetes to swim to the top of the substrate in an attempt to 'escape' the stun, thus allowing for their capture. Depletion fishing's were carried out where necessary. Note in heavily silted areas, electrofishing may need to be paused to allow the sediment to settle, thus allowing full visibility of the enclosure.

As with the fish and crayfish sampling methodologies, quantitative electrofishing methods were always employed using boat, bank based and back-pack electrofishing equipment, with the exception of the 10 minute Fish Population Index (FPI). Both the quantitative and qualitative surveys not only give measurements of presence/absence and length-frequency distribution, but they also give an indication of the effects of maintenance and capital works programmes on lamprey populations. Electrofishing ideally works in channels where there is a lot of sediment for the lamprey to utilize.

Qualitative spoil sampling can be undertaken to determine the presence/absence of lamprey in an area of channel. This involves examining the spoil placed on the bank immediately post maintenance, and collecting any lamprey found for processing. Similar to that of the white-clawed crayfish, quantitative spoil sampling using tarpaulin is a method which is employed by EREP in union with OPW staff. By measuring the diameters of the machine bucket, a known surface area of spoil is excavated and placed on a tarpaulin. Once on the tarpaulin the spoil is inspected, thus allowing information such as length-frequency distribution and the minimum population density of lamprey to be calculated. This survey can give invaluable insights into the potential impacts OPW works can have on a channel, and also which substrate type lamprey utilize, thus having in the implications for instream substrate management.

The sweep net sampling method involves using a hand-held kick sample net for a fixed period of time, in a predefined area of known size, thus giving an indication of lamprey presence/absence in a channel. This technique can only be undertaken in shallow wadeable channels, and work best in channels of suitable substrates.

3.7 Physical Survey Methodologies

A series of measurements of channel dimensions are made at specific transects in each site (bank-full width, wetted width, wetted perimeter, depth, velocity, canopy cover). These measurements are

taken annually at those sites where alteration or changes in these dimensions occur as a result of maintenance works. Transects are uniformly spaced, at 5 - 10m intervals.

General

- Express all measurements in metric units (metres, m/sec etc).
- Measure across transects from LHS to RHS.
- Take photos ACROSS and DIAGONAL TO marker transects to allow repeats. If possible including obvious landmarks in the landscape.
- Measure in an upstream direction moving from transect to transect (Bottom transect is T0).
- Measure distances between transects along the LEFT–HAND SIDE and along the WETTED EDGE of the channel with respect to the river's direction of flow ie. LHS as you look down-stream.
- Distance across transects to be measured along the line of wetted width and of Wbed (The'NORMAL' available flowing width). Wbed is only relevant in channels with gravel shoals/secondary banks etc. eg. Moynalty , Monaghan Blackwater, Owvane.
- Measure all variables across the transect at right angles to flow.
- Short study site (25-40m long) - sample at 5m intervals.
- Long study sites (100m+) – sample at 10 m intervals.

A 3-person crew is the "ideal" for physical surveys, two using tapes/chains/meters and one recording. Two is adequate, but can be slow and fine for cross-sections and velocity profiles. One is not permitted due to health and safety.

The latter two points will help remove bias in sampling BUT, in the case of treated sites, it is necessary to accurately and adequately measure altered and unaltered transects in the same treatment site.

Physical parameters to be measured

1) Wetted width (WW): Wetted width is measured wetted edge to wetted edge with a tape (Fig. 2). (The width of the stream at the waters surface).

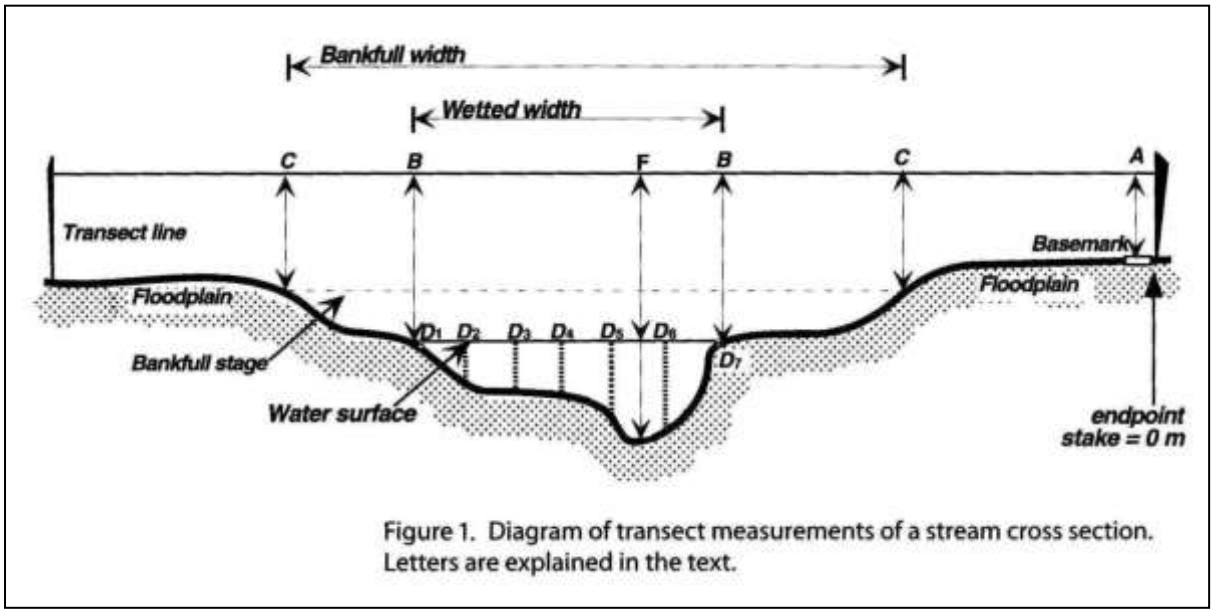


Figure 1. Diagram of transect measurements of a stream cross section. Letters are explained in the text.

Figure 2. Details the physical measurements undertaken in an EREP survey

2) Bankfull width:

Bankfull width (fig 1, C) is the maximum width the stream attains before topping the bank and flowing out onto the flood plain

3) Bed Width (Wbed):

This is different to WW as it includes a depositing gravel shoal or secondary bank. eg. Owvane, Moynalty. Measure to notional line at end of point bar where vegetation is growing or trash collecting.

4) Depth (D):

Depth is the vertical distance between the water surface and some point on the streambed, it is measured to the nearest cm using a metre stick/ survey staff. 5 readings are taken (evenly spaced) across the transect in the wetted width and 2 more, 1 at each margin within 0.05m of the wetted edge (Fig. 1, D 1-7). The latter two are designed to give an indication of depth at the edge and hence, degree of cover available (water depth at the waters edge is critical for fish especially young of the year). Depth can be displayed as a contour plot as in figure 3.

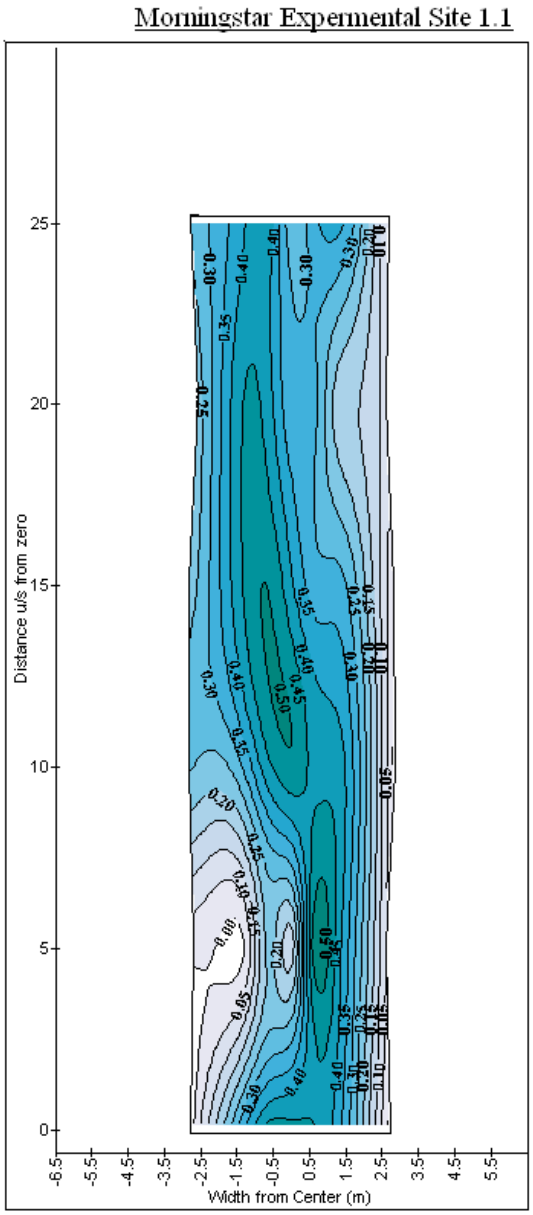


Figure 3. Depth contour plot for site 3 on the Morningstar experimental site in the Maigue Catchment, August 2008

5) Channel bed gradients

These are available from longitudinal profiles compiled by the Office of Public Works for each channel at the design stage of all drainage schemes.

6) Canopy Cover

Canopy cover is of significance in those locations where tree/shrub removal or thinning is envisaged. It provides a simple, repeatable and quantitative method of assessing the treatment impact on the

fishery habitat. Canopy density/closure is measured to the nearest percent using a concave Spherical Densiometer. Use a spherical densiometer to collect data on the extent of encroachment/ariel cover provided by trees and shrubs growing in the riparian zone.

(1) *Canopy closure* is the area of the sky over the stream channel that is screened by vegetation.

(2) *Canopy density* is the relative amount of the sky blocked within the closure by vegetation.

The densiometer consists of a curved concave reflecting mirror and has 37 grid intersection forming 24 squares. Only 17 of the line intersects are used as recording points by taping a right angle on the mirror surface as shown in Figure 4. Canopy density/closure is measured at 4 or 8 points in the stream depending on width.

Figure 4. Spherical densitometer modified with electrical tape to count 17 grid intersections

<u>Procedure</u>

1. Take readings on same transects used for compiling physical survey data
2. Hold the densiometer on the transect line perpendicular to the **left** streambank 30cm from and 30cm above the left water shore.
3. The arm from the hand to the elbow is horizontal to the water surface.
4. The densiometer is held away from the observer with the bottom of the V pointed toward the recorder. The densiometer must be kept level using the level bubble.
5. The grid between the V formed by the tape encloses 17 points. The number of points (line grid intersections) that are surrounded by vegetation (canopy closure) or are intercepted by vegetation (canopy density) are counted within the V outlined area (maximum of 17).
6. The same procedure as used on the left bank is used in the **centre** of the stream facing upstream to gain another reading and then another reading is taken facing downstream.

The last reading is taken at the **right** shoreline using exactly the same procedures used for the left bank (Platts *et al*., 1987).

7. The sum of intersections blocked by vegetation or other obstructions is added together from the four readings and multiplied by 1.5 to estimate percent canopy density. A correction is applied for rounding error; 1% is deducted from scores between 30 and 65% and 2 percent is deducted from scores over 66%. No deduction is made for scores between 0 and 29%.
8. For stream orders 5-7 (>20m), the same procedure is used except eight readings are taken across the transect (Fig. 3). Two additional readings, one facing upstream and one downstream are taken at the quarter and three-quarter interval along the transect. The eight recordings are totalled and multiplied by 0.75 to obtain percent canopy density. The correction for rounding error is applied: 1% deducted from scores between 30 and 65%. 2% from scores over 65%. No deduction is made for scores between 0 and 29% (Bauer and Burton 1993).
9. Obtain mean cover value for each transect and obtain mean value for full treatment site under investigation
10. Present graphic of canopy cover distribution over full site length for the 4 cardinal points measured.
11. It is very difficult to hold the instrument steady for long enough to get accurate readings for both canopy closure and canopy cover. Measure canopy cover at a minimum.

Canopy cover can be defined by 6 different classes (Brack, 1999).

1. Very Sparse 1-9%
2. Sparse 10-29%
3. Low 30-49%
4. Medium 50-69%
5. Dense 70-84%
6. Very Dense 85-100%

7) Velocity

Velocity (V) measurements are possibly most useful as depth/velocity profiles and contour plots (Fig. 5 & 6) across characteristic transects or site of cross-sections. Measure velocity for constant 'I' seconds and set this timing on the flow meter. Data collection is designed to give: (a) velocity and depth profile and (b) volume discharge.

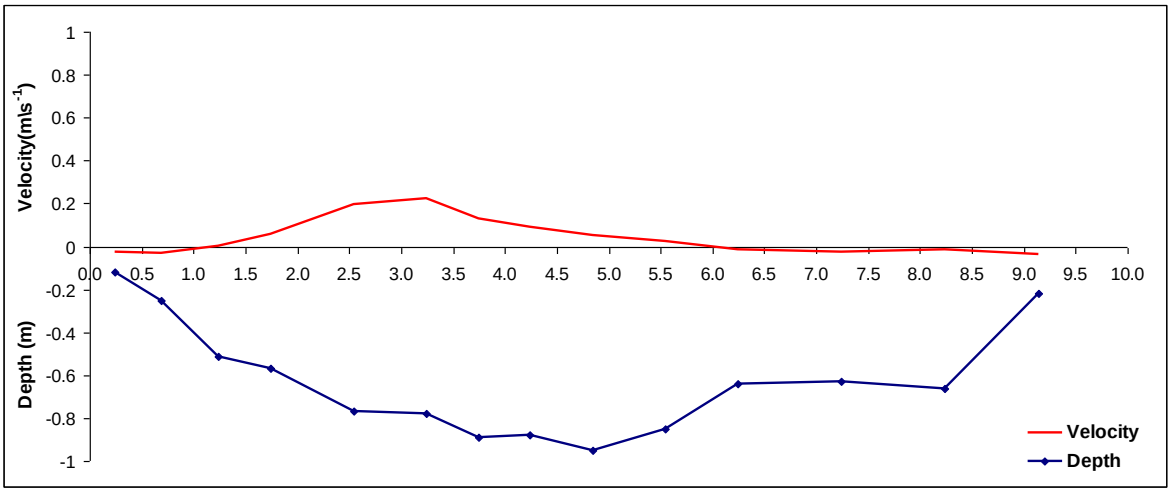
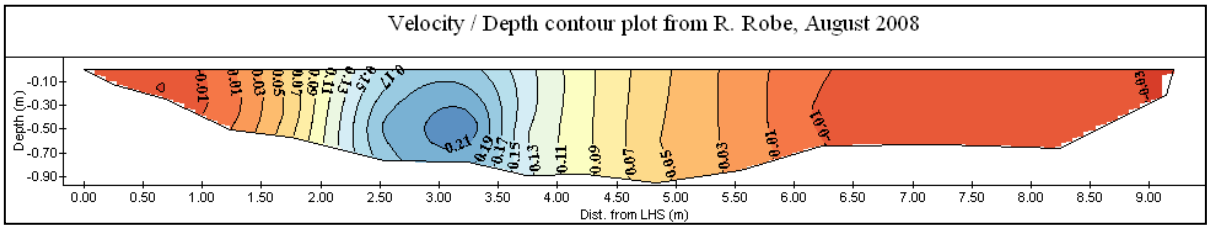


Figure 5: An example of a velocity-depth profile from R. Robe, Mayo August 2008.

Figure 6: An example of a velocity / depth contour plot from R. Robe, Mayo August 2008.



Procedure

- Velocity readings are taken using a Marsh McBirney Flow-mate portable flowmeter (electromagnetic). This type of meter was chosen as it can be used in situations where rotary meters cannot be operated, such as within clumps of vegetation. The meter is mounted on a top-setting wading rod, which allows the current meter to be easily set to the correct depth.
- A two person crew works best, one to operate the current meter and one to take notes.
- Stretch a tape between the endpoints of the wetted cross-section. Divide the wetted width by at least 13 to get the interval for reading the flow meter. Each subsection should have roughly the same amount of flow; therefore, verticals should be spaced more closely if the water is faster and deeper. Additional verticals are added where sudden changes in depth or velocity occur. (The 'Vertical' is the column of water of measured depth in which paired velocity and depth of probe measurements are taken to compile 'Q' value).
- The operator stands downstream and to one side of the instrument in a position that least affects the velocity of the water passing the meter (Platts *et al*., 1987).

- A practical guideline is to use about one vertical per metre of channel width, with more if the section is irregular and less if it is uniform (Gordon *et al*., 1992).
- Depth is measured upwards from the streambed.
- For measurements in small uniform streams a single measurement at 60% of depth (0.4D from bottom) is used.
- Three measurements (0.4D, 0.2D and 0.8D) should be taken if the velocity profile is distorted by overhanging vegetation or by large submerged objects.
- At each vertical, the horizontal distance from the left bank, the water depth and the current meter readings should be recorded.

8) Discharge

Discharge (Q) is the volume of water passing through a stream cross-section per unit time and is generally expressed as cubic meters per second (cumecs) (Harrelson *et al*., 1994). Discharge is calculated using the velocity-area method using a current meter. This requires the measurement of the area of a stream cross-section and the average velocity. Discharge is then calculated as Q= VA, where Q= discharge (m3/s), V= average velocity (m/s) and A= cross-sectional area of the water (m^2).

In order to calculate volume discharge 13 sets of verticals are required per wetted cross-section to develop a GOOD 'Q' value. This need only be developed in a single cross-section for any given sector of channel. However, in developing a good velocity profile it requires little extra effort to collect the additional data for estimation of 'Q'

(1) 3 depths of measuring in each vertical @ 0.1m below surface,
@ 0.5 of column depth,
@ 0.05m off stream bed,

OR

(2) 1 depth of measuring in each vertical @ 0.6 of depth (engineering convention)

Number (1) is better for giving greater range of velocities. This may be very significant in weeded transects.

WARNING: The greatest number of verticals is required in areas where most velocity is occurring. This is important in weeded areas where 'verticals' may have to be crowded into small 'preferred paths' of open water flow.

9) Channel Cross-Sectional Profiles

The purpose of taking cross-sections is to provide a visual impression of a channel cross-section, including all the space bounded by the natural floodplain on each bank. This impression can be compared with others, from the same place at a different time, or from a different place (in the same river or not) at the same time. The X-Y paired coordinates derived can be logged into AQUAPAK for reduction to develop area, hydraulic radius and depth etc. This programme does not provide a figure. EXCEL can be used to draw scaled drawings or the data can be loaded into EXCEL for subsequent import into graphic software.

In the EREP programme channel cross-sectional profiles are taken at representative locations to show the form of altered and unaltered channel sections. 3 cross-sections should be done per plot or per treatment. This should allow some statistical comparison. A profile can be obtained with a theodolite/dumpy-level (telescopic level), or in small streams, by using a measuring tape and metre rule or survey staff. The channels left bank is used as a reference zero. Fig. 1 gives the terminology for describing channel dimensions at a cross-section. A 30m tape is stretched horizontally across the channel and secured to steel rods at either side of the channel (Fig 1, Transect line). Vertical measurements are taken at several points along the horizontal line using an engineering staff and telescopic level. The horizontal distance to the measurement point and the vertical distance to the streambed are recorded. Measurements can be taken at each break in slope along the bed or at 0.5 to 1m intervals. The precise location and depth of water at each edge should also be recorded. Marginal and instream flora, if present, are recorded at each graduation. The survey should be continued past the edges of the active channel if the study involves monitoring of channel changes.

<u>Procedure</u>

(a) Take all measurements off the left bank as a standard. If this is not possible, state so clearly.

- Establish photo points and location. Measure to site from a permanent repeatable position (Bridge corner, Heavy duty fence post) and take photos upstream, downstream and across the channel. Try to include the entire cross-section with both end points and the tape in place, in the frame.
- A 50m tape is stretched horizontally, with as little slack as possible, across the channel and secured to steel rods at either side of the channel. Fix zero end of measuring tape at this point on LHS. This should become the reference zero if one wishes to repeat the cross-section at some future time.

- Set up telescope so that, ideally, it can view all 3 sections and can read the staff clearly at each. This will save time in setting up the telescope anew each time.
- Measure from top of the bank–full line, ideally on the horizontal and at the bank slope/bank-full interface.
- Vertical measurements are taken at several points along the horizontal line using an engineering staff and telescopic level. The horizontal distance to the measurement point and the vertical distance to the stream bed are recorded.
- The precise location and depth of water at the edges should also be recorded.
- Avoid the tops of isolated boulders and logs.
- Continue across the channel to the RHS stake. If necessary go beyond the stake to measure features on the far bank.

(b) In the absence of telescope, set up as in (a) with a graduated horizontal tape and read staff at each specified horizontal graduation at the point where the staff intersects the horizontal tape. Check for the best available horizontality by measuring the vertical height from the water surface to the graduated tape at the water's edge on both sides of the channel. If tape is horizontal, the vertical height should be the same in each reading.

(c) Shortcut method is to set up the telescope and take a level reading at each break in gradient across the cross-section from bank-full to bank-full. In addition to the level reading (centre cross-hairs in the telescope) both the upper and lower cross-hairs must be read and noted. These latter (stadia) facilitate calculation of distance from level to staff as follows: subtract the two readings, multiply answer by 100 and this is your horizontal distance in m.

Method **(a)** is preferred. Both **(a)** and **(b)** give considerable detail. In small channels up to approx. 8m wide, in terms of wetted width, spacing of 0.5m should be used. In those with larger values of wetted width, spacing of 1m should be adopted.

It is important in all cases to have a sufficient number of points recorded IN the wetted area (since this is of prime importance) to clearly delineate the form of the instream area in any graphical representation of the cross-section. It is also important to use the same method pre- and post-works to facilitate a comparison or overlay of the cross-sections.

When setting up sections which will be repeated in the future, some form of permanent referencing should be developed. This can take the following form(s):

- Constant zero point on LHS at slope\bank-full interface.

- Photo of cross-section with tape/telescope set up to show: Transect view across to show local markers and zero point; Diagonal view to show u/s or d/s perspective on the section.
- Permanent marker in the ground on both banks to indicate the two ends of the horizontal tape. The markers could take the form of short hollow lengths of metal tubing bedded into the ground. The only problem with such a method is in re-locating the tubes from year to year. They must be placed so that they are discreet and do not constitute a hazard to riparian owners or those using the river bank.

Bibliography

Abdel H. El-Shaarawi, Walter W. Piegorsch (2002). BACI Design, p141-148 in *Encyclopedia of Environmetrics*: V. 4. John Wiley and Sons.

Bailey, N. T. J. (1951) On estimating the size of mobile populations from recapture data. *Biometrika*, 38, 293-306.

Bauer, S. B.and Burton T. A. (1993). Monitoring protocols to evaluate water quality effects of grazing management of western rangeland streams. Seattle, WA, USA US Environmental Protection Agency (EPA), Region 10, Water Division. 166 p. Report EPA 910/R-93-017.

Brack, 1999 C. Brack, Forest measurement and modelling (1999) http://sres-associated.anu.edu.au/mensuration/crownclo.htm.

Caffrey, J. (1990) The Classification, ecology and dynamics of aquatic plant communities in some Irish Rivers. Unpublished Ph.D. Thesis presented to the National University of Ireland.

Carle, F. L. and Strub, M. R. (1978) A new method for estimating population size from removal data. *Biometrics*, **34**, 621-630.

Crawford, B.A., and L.E. Johnson. 2003. *Procedure For Monitoring Effectiveness Of Riparian Planting Projects.* MC-3. Final Draft. Washington Salmon Recovery Funding Board. 12 p.

Crisp, D. T., Mann, R. H. K. and McCormack, J. C. (1974) The populations of fish at Cow Green, Upper Teesdale, before impoundment. *Journal of Applied Ecology*, **11**, 969-996.

Gordon, N. D., McMahon, T. A. and Finlayson, B. L. (1992) *Stream Hydrology: An Introduction for Ecologists*. Wiley and Sons, Chichester.

Harrelson, C. C., Rawlins, C. L. and Potyondy, J. P. (1994) *Stream channel reference sites: an illustrated guide to field technique*. Gen. Tech. Rep. RM-245. Fort Collins, Co.: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61pp.

Hatton-Ellis TW & Grieve N (2003). *Ecology of Watercourses Characterised by* Ranunculion fluitantis *and* Callitricho-Batrachion *Vegetation.* Conserving Natura 2000 Rivers Ecology Series No. 11. English Nature, Peterborough.

Holmes NTH (1983). *Focus on Nature Conservation No.4.Typing British Rivers According to their Flora.* Nature Conservancy Council, Peterborough.

Holmes NTH, Boon P & Rowell T (1999). *Vegetation communities of British rivers: a revised classification*. Joint Nature Conservation Committee, Peterborough.

Life in UK Rivers (2003). Monitoring Watercourses Characterised by *Ranunculion fluitantis* and *Callitricho-Batrachion* Vegetation Communities. Conserving Natura 2000 Rivers. Monitoring Series No. 11, English Nature, Peterborough

Platts, W. S., Armour, C., Booth, G. D., Bryant, M., Bufford, J. L., Cuplin, P., Jensen, S., Lienkaemper, G. W., Minshall, G. W., Monsen, S. B., Nelson, R. L., Sedell, J. R. and Tuhy, J. S. (1987) Methods for evaluating riparian habitats with applications to management. General Technical Report INT-221. Ogden, UT; U.S. Departmnet of Agriculture, Forest Service, Intermountain Research Station; 1987. 177pp.

Seber, G. A. F. and Le Cren, E. D. (1967) Estimating population parameters from catches large relative to the population, 631-643.

Stewart-Oaten, A, W.W. Murdoch, and K.R. Parker. 1986. *Environmental Impact Assessment: "Pseudoreplication" in Time?* Ecology 67(4): 929-940.

Zippin, C. (1956) An evaluation of the removal method of estimating animal populations. *Biometrics*, 163-189.

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