Monitoring the River, Brook and Sea Lamprey

Lampetra fluviatilis, L. planeri and Petromyzon marinus

Conserving Natura 2000 Rivers

Monitoring Series No. 5

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Jon Harvey and Ian Cowx

International Fisheries Institute, University of Hull

For more information contact:
The Enquiry Service
English Nature
Northminster House
Peterborough
PE1 1UA
Email: enquiries@english-nature.org.uk
Tel: +44 (0) 1733 455100
Fax: +44 (0) 1733 455103

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Fax: +44 (0) 1733 455103

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Conserving Natura 2000 Rivers

This protocol for monitoring the river, brook and sea lamprey (*Lampetra fluviatilis, L. planeri and Petromyzon marinus*) has been produced as part of **Life in UK Rivers** – a project to develop methods for conserving the wildlife and habitats of rivers within the Natura 2000 network of protected European sites. The project's focus has been the conservation of rivers identified as Special Areas of Conservation (SACs) and of relevant habitats and species listed in annexes I and II of the European Union Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC) (the Habitats Directive).

One of the main products is a set of methods for monitoring species and habitats, which complements reports containing the best available information on their ecological requirements. Each report has been compiled by ecologists who are studying these species and habitats in the UK, and has been subject to peer review, including scrutiny by a Technical Advisory Group established by the project partners. In the case of the monitoring techniques, further refinement has been accomplished by field-testing and by workshops involving experts and conservation practitioners.

Conservation strategies have also been produced for seven different SAC rivers in the UK. In these, you can see how the statutory conservation and environment agencies have developed objectives for the conservation of the habitats and species, and drawn up action plans with their local partners for achieving 'favourable conservation status'.

Life in UK Rivers is a demonstration project and, although the reports have no official status in the implementation of the directive, they are intended as a helpful source of information for organisations trying to set conservation objectives and to monitor for 'favourable conservation status' for these habitats and species. They can also be used to help assess plans and projects affecting Natura 2000 sites, as required by Article 6.3 of the directive.

Favourable conservation status

The purpose of designating and managing SACs is to maintain at, or restore to, 'favourable conservation status' the habitats and species listed on annexes I and II of the directive.

The conservation status of a natural habitat can be taken as favourable when:

- Its natural range and areas it covers within that range are stable or increasing.
- The specific structure and functions necessary for its long-term maintenance exist and are likely to exist for the foreseeable future.
- The conservation status of its typical species is favourable.

The conservation status of a species may be taken as favourable when:

- Population data indicate that the species is maintaining itself on a long-term basis as a viable component of its natural habitats.
- The species' natural range is neither being reduced nor is likely to be reduced for the foreseeable future.
- There is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis.

The conservation status of a species or habitat has thus to be assessed across its entire natural range within the European Union, in both protected sites and the wider countryside, and over the long term.

Monitoring techniques

The Habitats Directive requires the condition of the habitats and species for which an SAC has been designated to be monitored, so that an evaluation can be made of the conservation status of these features and the effectiveness of management plans. An assessment of conservation status must, therefore, be applied at both site and network level.

Standard monitoring methods and a coherent assessment and reporting framework are essential to allow results to be both compared and aggregated within and across EU member states.

While the directive outlines the data reporting required from member states at a national level, it did not set out detailed assessment techniques for data collection at habitat and species level.

The Conserving Natura 2000 Rivers series of monitoring protocols seeks to identify monitoring methods and sampling strategies for riverine species and the *Ranunculus* habitat type that are field-tested, cost-effective, and founded on best scientific knowledge.

Titles in the monitoring and ecology series are listed inside the back cover of this report, and copies of these, together with other project publications, are available on the project website: www.riverlife.org.uk.

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Executive summary

Background

The Habitats Directive stipulates that member states maintain or restore habitats and species to ensure their favourable conservation status in the community. To comply with this directive, a number of rivers have been designated Special Areas of Conservation (SACs) because they support important populations of vulnerable designated species. This report describes a standardised protocol to monitor lamprey populations in SAC rivers to assess the conservation status of the species against a predetermined set of objectives.

A review of the lamprey ecological and habitat needs concluded that the key features that dictate their distribution and abundance are: water depth, water velocity and substratum composition (Maitland 2003).

Lamprey ammocoete condition assessment

Three strategies are proposed for assessment of the conservation status of lamprey ammocoete populations in SAC rivers.

1. Abundance classification

The first approach classifies the density of lamprey ammocoetes in order to define the relative condition of fish populations in rivers. This assessment is based on two measures – the first a density estimate based on optimal habitat, and the second a density estimate based on catchment-wide surveys that will include a diversity of habitats. The attributes for compliance with favourable status are tentatively set at:

Optimal habitat

- Population density river/brook lamprey ammocoetes — $>10\ m^{-2}$
- Population density river/brook lamprey ammocoetes chalk streams — $>5\ m^{-2}$
- Population density sea lamprey ammocoetes — $0.2\ m^{-2}$

Catchment perspective

- Population density river/brook lamprey ammocoetes — $>2\ m^{-2}$
- Population density sea lamprey ammocoetes — $0.1\ m^{-2}$

Abundances less than these targets indicate rivers/reaches/sites in unfavourable condition. It is important that an appropriate number of sites are surveyed to account for natural spatial variation in lamprey population size in the SAC rivers under examination.

2. Population demographic structure

A second assessment can be made of the demographic structure of the population – that is, the contribution of different age classes to the population to demonstrate recruitment success. To achieve favourable conservation status, where abundant, river and brook lamprey ammocoete populations should have at least two age classes in the populations sampled from optimal habitat. Deviation from compliance should not occur in more than one year in three.

3. Distribution

Further assessment of the status of lampreys can be derived from mapping their distribution in individual SAC rivers. Compliance with favourable conservation status should be recorded if there is no decline in distribution of ammocoetes from the current, or where available, historical pattern. This distribution pattern should be linked to favourable habitat status, whereby no deterioration in habitat quality is registered.

Monitoring strategy

To provide an overview of the status of lamprey ammocoete populations in SAC river catchments, monitoring by quadrat-based electric fishing is recommended. A combination of quantitative (multi-run depletion method) and semi-quantitative (calibration method) sampling is recommended.

Before undertaking fisheries surveys the appropriate access and fishing rights should be obtained. Electric fishing surveys should comply with all national health and safety regulations. Standard data recording forms are recommended for reporting fisheries and environmental data. The data input forms for River Habitat Surveys or HABSCORE are recommended for recording environmental and physicochemical data.

Surveys should be conducted between August and October. Annual surveys on index sites, the number of which is determined using classical statistical sampling designs, are recommended. Every six years, catchment-wide surveys should be carried out to review compliance. Sampling tributaries outside the boundaries of the SAC river must be included in the survey design, as these may contribute significantly to the well-being of the stock in the catchment.

Standard reporting procedures used by the appropriate agencies in each country should be used. It is recommended that all information is stored on a central database, such as those available in the Environment Agency or the Scottish Fisheries Coordination Centre (SFCC). Outputs from the lamprey ammocoete surveys will be interpreted in relation to compliance with favourable conservation status. Reasons for failure will be determined from environmental and physiochemical data collected parallel to the fisheries surveys.

Case studies: rivers Eden and Teifi

Case studies for the SAC rivers Eden and Teifi are provided in this report. These include a programme of monitoring and resource requirements.

1 Introduction

To manage fish species of conservation value in SAC rivers against a set of conservation objectives requires a monitoring programme that will establish the status of the species against a predetermined set of conservation objectives: a process known in the UK as 'condition assessment'. This is carried out at individual sites, and can contribute to an assessment of the conservation status of each species across its geographical range in the UK.

Condition assessments for habitats and species are recorded using one of the following categories:

- Favourable
- Unfavourable
  - Declining
  - Maintained
  - Recovering
- Partially destroyed (habitats)
- Destroyed (habitats).

The condition assessment must provide information on the present status of the species and give at least a broad indication of trends. Sampling strategies must therefore be able to detect any change over a period of years or differences between sites. The ability to compare different sites is important because each SAC river may exhibit different habitat characteristics related to size, depth and gradient of the river. Habitat information is also needed to provide a broad overview of the present and future health of the population.

The objective of this report is to define survey, monitoring and reporting procedures to inform the assessment of the condition of populations of three species of lamprey in SAC rivers: river lamprey (*Lampetra fluviatilis*), brook lamprey (*L. planeri*) and sea lamprey (*Petromyzon marinus*). It is recognised that this process must be carried out efficiently, so the protocols proposed are based on the minimum cost-effective strategies needed to provide information for accurate assessment of species status.

This report is broken down into a number of sections to meet these objectives. Firstly, the biology and habitat requirements of the lamprey species found in UK rivers are reviewed, to identify the key parameters that will help assess the conservation status of stocks, and the main environmental factors that may affect their status. This information is then used to evaluate the monitoring needs for lamprey populations in rivers and formulate the appropriate strategy. Finally, the mechanisms for establishing conservation targets for sustainability of specific stocks are described.

2 Ecology and habitat requirements of lamprey

The ecological requirements of lampreys have been described in detail in the literature and reviewed by Maitland (2003). The key features are described below.

All three species found in UK rivers are widely distributed throughout the British Isles, although sea and river lamprey are only reported occasionally north of the Scottish Great Glen (Maitland & Campbell 1992, R. Gardiner pers. comm.).

Both sea and river lampreys are anadromous, with adults typically inhabiting coastal and offshore waters (Maitland *et al.* 1994). The brook lamprey is a non-parasitic species that spends its whole life cycle in fresh water.

All three species spawn in fresh waters, and juveniles of all three species, known as ammocoetes, are found within the same catchments, using similar microhabitats, but with varying geographical distribution. Sea lampreys are typically found in the lower reaches of rivers, while river and brook lamprey are more closely associated with the middle and upper catchment, where their ranges often overlap.

Lamprey habitat preferences appear to change with the stages of their life cycle (APEM 2001, Maitland 2003). They show a preference for gravel-dominated substratum for spawning, and mainly silt and sand-dominated substratum for nursery habitat. Other important environmental characteristics for optimal ammocoete habitat are shallow waters with low water velocity, and the presence of organic detritus and/or plant material. Sub-optimal habitat supporting only a few individuals may consist of a few square centimetres of suitable silt in an open, comparatively high-velocity, boulder-strewn streambed. Spate rivers, with high flow velocities, tend to support fewer ammocoetes because they contain smaller areas of stable sediment.

3 Existing monitoring methods

Lampreys are rarely the target of intensive field studies in the UK. Consequently, they are usually only recorded as present (possibly on a subjective abundance scale) or absent in routine electric fishing surveys. APEM (2001) reviewed the literature and undertook trials on sampling methods for ammocoetes, and concluded that four had potential for quantitative assessment. These were:

- Visual observation
- Trapping and netting
- Semi-quantitative electric fishing of specific areas
- Quantitative electric fishing of quadrats.

They indicated that both visual and trapping methods had previously been used to sample either migratory adults or the dispersal phase of pro-ammocoetes, and neither technique was fully quantitative.

APEM (2001) finally considered that an electric fishing-based technique is best suited to the production of replicable, statistically robust data, which can be used to assess ammocoete population status, calculate population density and provide information on age structure. It was concluded that quadrat-based electric fishing, as described by Gardiner *et al*. (1995), is most suitable for sampling in open channels but caused problems where there is patchy distribution of silt associated with aquatic macrophyte beds.

Multiple sampling within a quadrat also enables quantitative estimation of population density with an associated measure of sampling efficiency. APEM (2001) recommended the use of this technique in association with depletion sampling of isolated standard $1m^2$ quadrats. However, this does not allow assessment in sub-optimal habitat and areas in association with macrophyte beds. Consequently, a semi-quantitative electric fishing method, in which a relative measure of abundance can be determined, is also required. It is thus recommended that quadrat-based electric fishing, supported by semi-quantitative sampling of sub-optimal habitat, is used for condition assessment of lamprey ammocoetes in SAC rivers.

4 Sampling lamprey ammocoetes

The objective of the following sampling protocol is to detect changes in lamprey ammocoete populations of the three species in order to determine conservation status and to allow appropriate management intervention.

Two approaches to determine the distribution and abundance of lamprey ammocoetes in SAC rivers are proposed. The first targets abundance of ammocoetes in optimal habitat where abundance is expected to be high and the populations underpin the long-term sustainability of the stocks. The second approach focuses on the distribution and abundance of ammocoetes from a catchment perspective, targeting both optimal and sub-optimal habitat. In this context, optimal habitat is defined as stable fine sediment or sand ≥ 15 cm deep, low water velocity and the presence of organic detritus (APEM 2002). Sub-optimal habitat is defined as shallow sediment, often patchy and interspersed among coarser substrate (APEM 2002).

Field studies on the River Eden and Afon Teifi (Harvey & Cowx in prep.) suggested that sub-optimal habitat should also include areas of organic detritus overlying bedrock, submerged tree roots trapping organic material, submerged silt banks, silt-dominated cattle drinks, and submerged bankside vegetation rooted in sand/silt. These latter sub-optimal habitats are likely to be temporary refuges due to their unstable nature in the event of floods. However, investigation of their use by lamprey ammocoetes is important.

The sampling protocol is based largely on stand-alone surveys because existing monitoring programmes targeting juvenile salmonids tend to be in areas not necessarily frequented by lamprey ammocoetes. However, where possible, attempts should be made to combine monitoring of lamprey ammocoetes with routine juvenile salmonid monitoring. The use of existing salmonid monitoring sites has a number of advantages:

- Existing sites are generally situated near bridges, and older structures are often in areas where silt accumulates, providing optimal habitat conditions.
- Existing sites are likely to have areas of sub-optimal habitat (e.g. organic material, shallow sediment) where ammocoetes may be present.
- Existing sites are usually well distributed through a particular catchment, which will provide information on ammocoete distribution.
- Ammocoete sampling may be undertaken following salmonid and bullhead surveys, thus avoiding the need for a repeat visit to the catchment. This would considerably decrease survey costs.
- The presence/absence of lampreys is usually recorded in juvenile salmonid monitoring. Hence, re-interrogating existing historical databases will reveal information on presence/absence of lamprey.
- Riparian-owner and fishery-owner access permissions are already agreed, thus avoiding the need for lengthy discussions concerning access.

Additional observational studies on the spawning activities of the three lamprey species are also proposed (see Section 5).

4.1 Site selection

As electric fishing will be undertaken to provide an overall condition assessment of the SAC river catchment, sites selected must represent the distribution and abundance of the lamprey populations of each species. Previous studies on all SAC rivers should enable fisheries scientists to establish, at least approximately, where the upper and lower limits of the different species are within each SAC. It is important that sampling sites on tributaries outside the boundaries of SACs are included, as these may contribute significantly to the sustainability of lamprey populations in the SAC as a whole. Particular attention should be paid to barriers to migration of adult sea and river lamprey, as these can severely restrict the distribution of these species within a catchment and affect its conservation status.

The proposed assessment of conservation status is based on achieving ammocoete density targets in all habitat types (optimal and sub-optimal). Consequently, selected sites must contain both types of habitat. The first stage of site selection therefore necessitates a review of the river habitat characteristics. Ideally a walk-over survey of the river is needed to identify large areas of optimal habitat. However, this is time-consuming, and, in the UK, local knowledge linked to River Habitat Survey (RHS) data should provide a good overview to identify such sites. Limited surveillance of the river may be necessary. This is particularly important in SAC rivers like the Eden and Teifi because optimal habitat is restricted in the middle and upper reaches due to the topography, underlying geology and flow regimes.

Consideration should also be given to sampling sites where lamprey ammocoetes would not normally be expected. An example of this was found in surveys in the Teifi catchment where a high abundance of ammocoetes was found 10 m downstream of a sewage outfall. Pollution sources can seriously damage spawning areas and smother silt beds. However, pollution levels below sewage outfalls may be sufficiently low to allow sustained use of silt beds by ammocoetes.

In selecting sites, it is imperative that a disproportionately high number of sites is allocated to the lower reaches of the main river stem, as sea lamprey ammocoetes are less abundant than river and brook lamprey ammocoetes, and more sites may be needed to detect them. This is especially important where barriers prevent upstream migration of sea and river lamprey to spawning grounds.

4.2 Sampling methodology

The use of electric fishing for sampling ammocoetes should follow a standard procedure to ensure comparison of data within rivers and between rivers. This may allow identification of population trends between years and indicate any improvement or decline.

The following section details the sampling protocol for ammocoetes. Since the methodology involves a separate surveying technique to that typically employed in the UK for bullheads or juvenile salmon, sampling for ammocoetes needs to be undertaken separately from, or in addition to, other fisheries surveys. The protocol describes the procedures for assessing an area of river to provide an indication of ammocoete abundance and population structure (size).

4.2.1 Survey equipment and safety procedures

The principal sampling gear recommended for abundance assessment of ammocoetes is electric fishing within a rigid quadrat framework with a base area of 1 m^2 to delimit the sampling area (Figure 1). The base of the quadrat framework should be constructed of lightweight interlocking tubing (electric conduit tubing is ideal). Four vertical, interlocking tubes emerge from the corners of the quadrat base to provide a rigid three-dimensional structure that encloses the sampling area. The four vertical walls of the quadrat framework are enclosed by fine mesh netting (mosquito netting or 2 mm mesh) to prevent the escape of lamprey from the sampling area. The top of the quadrat is not enclosed with netting to allow access for hand-netting of immobilised ammocoetes.

The quadrat framework is constructed so as to be free-standing on any substrate type. The use of interlocking tubing to provide rigidity allows the unit to be dismantled for transportation between sampling sites.

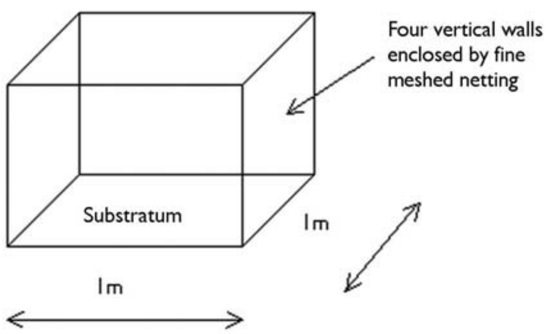

Figure 1. Rigid quadrat framework for sampling 1 m^2 area of sediment for lamprey ammocoetes.

In sub-optimal habitat, traditional hand-held electric fishing gear is recommended. Electric fishing is commonly used on a variety of waterbodies throughout the UK. Stringent guidelines for the design of the electric fishing gear, operation and safety regulations, produced by the Environment Agency and other UK fishery agencies, should be adhered to in all surveys (for example, the Environment Agency Code of Practice for Safety in Electric Fishing Operations, 2000). All personnel involved in electric fishing activities must have been fully trained to Environment Agency or equivalent standards, and the risks involved and safety procedures fully understood before any survey work.

General equipment and materials (clothing, lifejackets, hand nets, fish containers, communication equipment, first-aid kit) should meet the recommendations of the European Committee for Standardisation (Comité Européen de Normalisation; CEN) directive (CEN 2001). Before carrying out any fieldwork a full risk assessment of the work should be produced. This should include procedures for action in case of emergency.

4.2.2 Sampling procedure

Electric fishing can be carried out either using a bankside generator supply or back-pack gear. The waveform used should be either pulsed direct current (pulsed DC), or continuous direct current, but the latter must be turned on and off continuously to avoid immobilising ammocoetes in the sediment, making their capture difficult. With DC, care must be taken to ensure that the voltage is not too low (mainly because of low conductivity water) and the ammocoetes are not attracted to the anode.

Following identification of a suitable survey area (optimal or sub-optimal habitat) the rigid quadrat framework should be placed in the survey area and left for five minutes to allow any disturbed sediment to settle. For pulsed DC, a single anode is used to energise the substrate area within the rigid quadrat framework. The anode should be placed under the water surface but not directly onto the substrate surface (about 10–15 cm above the surface) as this may immobilise ammocoetes in the sediment. The anode should be energised for 20 seconds, then turned off for approximately five seconds. The anode should be switched on and off in this way for approximately two minutes. This method of energising the anode reduces the risk of immobilising ammocoetes in the sediment and making their capture difficult. Furthermore, the on-off cycle draws ammocoetes out of their burrows into the water column.

The anode operator should be helped by an assistant who removes immobilised ammocoetes using a fine-mesh hand net (for example, a net used for sampling invertebrates). The captured ammocoetes should be transferred to a suitable water-filled container.

Once the survey period of two minutes has elapsed, the electric fishing gear should be switched off (following Environment Agency procedures). For depletion sampling purposes the process should be repeated a minimum of three times, with a resting period of five minutes between each sample. Ammocoetes should be placed in a separate water-filled container for each sample.

Following completion of the sample the ammocoetes should be identified and measured (Section 4.2.6). The rigid quadrat framework can then be moved to the next sampling point and left to allow any disturbed sediment to settle while the first sample catch is processed.

Electric fishing in sub-optimal habitat requires a defined area of riverbed or instream vegetation, debris, or tree roots to be sampled. The same electric fishing gear used for the quadrat-based fishing should be used, but the power turned on and off frequently to draw the ammocoetes out of their burrows or from concealed locations. The area sampled should be measured accurately so the number of ammocoetes per unit area can be determined as a minimum estimate of density.

4.2.3 Presence of sea and river lamprey ammocoetes

Before carrying out a monitoring programme for ammocoetes, it is recommended that River Habitat Survey (RHS) data are collected or re-analysed for the study catchment. Sea and river lamprey migrate to the sea as part of their life cycle before returning to fresh water to spawn. Analysis of RHS data or Environment Agency flood defence data may allow the identification of any barriers to migration of sea and river lamprey. Barriers may be natural (waterfalls) or artificial (dams, weirs or pollution), and should be identified in the main river stem and tributaries of the SAC river. If natural and/or man-made structures are identified that would stop sea and river lamprey migration, then all ammocoetes caught upstream of these structures should be considered brook lamprey.

4.2.4 Size of survey site

Field trials of the above methodology on the River Eden and Afon Teifi showed that the technique is suitable for monitoring ammocoetes in both optimal and sub-optimal habitats. It is therefore recommended that optimal and sub-optimal habitats for ammocoetes are sampled with $1 m^2$ quadrats in a 100 m stretch of river at each survey site. Inclusion of sub-optimal habitat is considered important because many small areas of silt may contribute significantly to the overall abundance of ammocoetes in a catchment. The number of samples will be determined by the area and diversity of optimal and sub-optimal habitats at a particular survey site. However, a minimum of three data points is required.

The sampling of some sub-optimal habitats (for example, undercut banks or submerged tree roots with organic material) may preclude the use of $1 m^2$ quadrats and in these situations relative assessment of a measured area (number of ammocoetes collected by one run over a measured area as a minimum estimate of density) is recommended.

4.2.5 Timing of surveys

The timing of surveys for ammocoetes is important to ensure capture of a range of size-classes that includes both young ammocoetes and transformers (juveniles transforming into adult lamprey). Metamorphosis usually takes place between July and September. It is therefore recommended that surveys are carried out in July at the earliest, but preferably between August and October, to detect the presence of transformed ammocoetes. This is the same time recommended for bullhead sampling and for monitoring salmonids, so costs should be reduced if the lamprey survey can be done at the same time.

4.2.6 Fish data collection

Ammocoetes can be identified (to species level, if possible) in the field using the key by Gardiner (2003). To aid identification the use of a smooth white board and appropriate magnifiers are recommended. The identification of ammocoetes and transformers to the following categories should be possible for surveys carried out between August and October:

- River/brook lamprey ammocoetes
- Sea lamprey ammocoetes
- River/brook lamprey transformers
- Sea lamprey transformers.

It should be noted that identification of ammocoetes to river or brook lamprey before transformation is not possible in the field using external characteristics. However, it may be possible to distinguish river or brook lamprey transformers by late autumn/early winter (Gardiner 2003).

The use of anaesthetics is recommended to assist in identification and measurement of ammocoetes (Gardiner 2003). MS222 is known to perform well with ammocoetes. Benzocaine can also be used, but requires more care to avoid the induction of deep anaesthesia with associated slow recovery. Alternatively, to measure their length it is possible to use a curved gutter pipe with a plastic ruler in the base to prevent the ammocoetes moving too much. The collection of information on length is critical as analysis of age structure of the sampled population will rely on assessment of length frequency distribution.

Lampreys should be handled in such a way to minimise damage. Where there is a risk of transfer of alien species or pathogen agents, equipment should be disinfected. Following collection of data, all ammocoetes should be returned to the exact area of substrate sampled to ensure they are able to burrow into the sediment and avoid downstream displacement by the current. This is critical if suitable habitat is sparse at the survey site.

4.2.7 Environmental monitoring

Environmental information should be collected on each sampling occasion. The primary information needed is listed in Box 1. In addition, a habitat survey should be carried out every 10 years. Standard measurement procedures, such as those outlined in Bain & Stevenson (1999), and developed under the Environment Agency's RHS or HABSCORE protocols, should be adopted. It is essential that the habitat assessment includes a review of factors that may contribute to a river's failure of the condition assessment so due action can be made to rehabilitate it where appropriate.

4.3 Number of sites and frequency of sampling

Before identifying possible mechanisms for undertaking studies to define whether a river is in favourable or unfavourable condition, it is important to consider the desired information with respect to individual populations, and the accuracy and precision that must be achieved. In this context, accuracy is associated with the type of error or bias in the data. Poor accuracy tends to lead to assessments that considerably, but consistently, over- or under-estimate. Precision is associated with the "noise" (usually expressed as the variance or coefficient of variation, CV, of the estimate [CV = (standard deviation among sites)/(population mean) for abundance (fish/site)]) generated by the sampling procedure, and is usually reduced by larger sample sizes or repetitive surveys (Southwood 1978).

A highly reliable estimate will have a low coefficient of variation. The required precision in the stock estimate dictates the change in stock parameters that needs to be detected, i.e. if population parameters are being determined, the required precision of the estimated abundance or magnitude of change (spatial or temporal) that needs to be detected must be determined in relation to the objectives. This minimises the risk of obtaining a precision too low or high for the purpose. As the choice of precision level will strongly affect the resource input, it is worth considering this question in relation to the objectives at the planning stage. Bohlin *et al*. (1990) suggested a rough guide for establishing precision levels for fisheries surveys based on three categories.

- **Class 1**: Studies in this class require a very high level of precision; a population change in time or space by a factor as small as 1.2 (e.g. 83 << 100 >> 120) has to be detected with about 80% probability when using a 5% significance level. In the case of an independent estimation, this level of precision corresponds approximately to a coefficient of variation not larger than about 0.05.
- **Class 2**: Studies in this class require a medium level of precision; a population change in time or space by a factor as small as 1.5 (e.g. 67 << 100 >> 150) has to be detected with about 80% probability when using a 5% significance level. In the case of an independent estimation, this level of precision corresponds approximately to a coefficient of variation not larger than about 0.10
- **Class 3**: Studies in this class require a lower level of precision; a population change in time or space by a factor as small as 2.0 (e.g. 50 << 100 >> 200) has to be detected with about 80% probability when using a 5% significance level. In the case of an independent estimation, this level of precision corresponds approximately to a coefficient of variation not larger than about 0.16.

For detection of spatial and temporal changes in lamprey ammocoete populations in SAC rivers, precision levels 2 or even 3 are deemed acceptable (Cowx 1996). Detection of large scale shifts in the population characteristics that prevail over a number of years or between sites are considered adequate for meeting the objectives of assessing conservation status. This has distinct advantages since the number of sites in a particular reach that must be sampled can be reduced, thus reducing resource needs for surveying.

To determine the actual number of sampling sites that must be sampled, Bohlin *et al*. (1990) and Wyatt & Lacey (1994) provided detailed guidelines for fisheries survey design and analysis for various likely scenarios. These guidelines should be referred to if more detailed understanding of the principles

Box 1. Environmental variables and data to be collected during routine monitoring of lampreys in SAC rivers.

Sampling site, staff and objective

- Sampling site (name)
- Type of water (stream, river)
- River/stream (name)
- Catchment name
- Geographic locality co-ordinates (e.g. by GPS or six-figure National Grid Reference)
- Team (fishing staff leader and crew members)
- Fishing method (quadrat, relative assessment, depletion)
- Date (day-month-year)
- Time of the day (beginning and end of sampling)

Equipment and prerequisites

- Electric fishing equipment (manufacturer and model)
- Portable or non-portable (back-pack or generator based)
- Pulse type (DC or PDC)
- Pulse frequency (Hz)
- Voltage (V)
- Current (A)
- Water level (low, intermediate) (Fishing at high flows should be avoided)
- Weather conditions (air temperature, precipitation, cloudiness, windiness)
- Resistance or conductivity value of water ($\mu S\ cm^{-1}$)
- Temperature of water (°C)
- Visibility (colour and/or turbidity of the water)
- Anode type (anode diameter, number of anodes)
- Number of sampling points per survey site

General site details

- Average width of wetted area (m)
- Average depth (m)
- Maximum depth (m)
- Water current class – slow, intermediate, rapids and estimated current speed ($m\ s^{-1}$)
- Aquatic vegetation (absent, sparse, intermediate, species-rich)
- Dominating type of aquatic vegetation (submerged, floating, emergent)
- Classification of surrounding riparian zone (urban, grazing, arable, forestry)
- Shade
- Presence of woody debris
- Altitude
- Pollution sources
- Habitat degradation
- Stream gradient (slope per thousand)
- Secchi depth (m)
- Photographic documentation

Site details at each sampling point

- Sample area (m^2)
- Habitat classification (optimal, sub-optimal, none)
- Sediment type (silt, sand, mud, gravel)
- % contribution of each sediment type in sample area
- Depth of sediment (cm)
- % of organic material

Catch details at each sampling point

- Number and length (mm) of river/brook lamprey ammocoetes
- Number and length (mm) of sea lamprey ammocoetes
- Number and length (mm) of river/brook lamprey transformers
- Number and length (mm) of sea lamprey transformers

underlying sampling theory is needed. To determine the number of sites to be sampled, consider the case where stock size or mean density is assessed by a specific relative (catch per unit area or river bank length) or absolute method (Zippin or Carle & Strub) at each site. The precision is chosen as one of the classes previously suggested (CV = 0.16 for lamprey ammocoetes). The number of sites is determined from:

$$n = S(C_{pop}^2 + CV(\bar{N_i})^2 / (S \times CV^2 + C_{pop}^2)$$

where S is the number of possible sampling sites in the target area, C_{pop} is the spatial variation of population size among sites expressed as the coefficient of variation (standard deviation/mean) and CV(Ni) is the within-sites sampling error, expressed as the coefficient of variation (standard error/population size Ni) and CV precision-class required expressed as standard error/mean (for purposes of lamprey ammocoetes CV = 0.16, see above). It is therefore necessary to have a measure of the variance in densities of the target population from surveys in the area being sampled before one can calculate the minimum sample number for the given precision level. The CV(Ni) can be determined from a pilot study or from data from similar populations collected during routine monitoring programmes (see example from rivers Eden and Teifi, Section 7). The following example clarifies the application of the method.

In a upland river, the target area is sampled, as described below, at seven sites. The mean population size per section and the standard deviation among sites were 127 and 86, respectively. C_{pop} is therefore 86/127 = 0.68. To calculate the within-sites sampling error, a measure of catch efficiency is required, which must be derived from a multiple-catch depletion sampling, such as used for calibration of sampling efficiency. The catch probability (P) using Zippin or Carle & Strub estimates (see Cowx 1983) was 0.60. Therefore, CV_i can be calculated as follows, using P = 0.60, number of removals k = 3, and an average populations size N = 127. The sampling variance is determined as:

$$V(Ni) = Ni[(1-q^k)q^k] / [(1-q^k)^2 - (kP)^2 q^{k-1}]$$

where P is catch probability, and q = 1–P. The standard error of the population is the root of this expression. The CV is then:

$$CV(N_i) = \sqrt{[V(N_i)]} / N_i$$

For the example, CV(Ni) = 0.024. Finally, if the precision level of the assessment is set as Class 3 (CV = 0.16), the number of sites (n) required would be of the order of

$$n = 92(0.68^2 + 0.024^2) / ((92 \times 0.16^2) + 0.68^2) = 15.1 = 15.$$

If the level of precision is restricted to Class 2 (CV = 0.10), the sample size would be about 31, and for Class 1 (CV = 0.05) about 62 sites.

Input data for undertaking the above procedure are gained either from existing surveys on the river catchment or from preliminary field studies on the target catchment – for example, studies on the rivers and Eden and Teifi (Section 7). Such data probably do not exist for lamprey ammocoetes as they are rarely sampled quantitatively, but as a rule of thumb, approximately 40 sites should be surveyed in UK river catchments to provide an acceptable level of precision of ammocoetes abundance.

Lamprey ammocoetes generally stay in fresh water for several years, so the frequency of surveying is critical to identify any trends in the populations. It is recommended that surveys are carried out on an annual basis to ensure identification of 0+ ammocoetes so as to identify any impact on recruitment in a particular study year. The absence of 0+ ammocoetes from a study site containing >1+ ammocoetes may indicate poor recruitment to the population.

4.4 Results and reporting

The results for ammocoetes and transformers should be presented separately for each sampling site. The information should include:

- A list of fish species.
- Abundance of ammocoetes and transformers. These should be reported both as total numbers and as numbers per m^2, where possible for each species, derived either as a relative measure in terms of numbers caught per unit area, or as an absolute estimate using the appropriate Zippin or Carle & Strub depletion model on successive catches.
- Size structure. Length frequency histograms should be plotted and age structure determined from these. Mean length at age, including standard deviation, should be derived from length frequency histograms.

Reports should also contain detailed information on the sampling site, procedure and equipment, physiographical data, sampling conditions, results of catches, and any other relevant information regarding the survey (such as access problems, changes to site, etc.). An example of a baseline survey report form is given in Appendix 1, and the form for recording environment and habitat data for determining condition is given in Appendix 2.

It is recommended that all data are transferred to a common database using a standard format. In the UK, the current Environment Agency National Fish Population Database (NFPD) should prove sufficient for entering lamprey data. The Scottish Fisheries Coordination Centre (SFCC) database should be evaluated to ensure it is compatible with the NFPD database and that information is transferable. Ownership and confidentiality of data may be an important issue, and it is recommended that the conservation agencies, environmental regulators and fisheries interests develop a Memorandum of Understanding (MoU) regarding availability and use of any datasets generated.

4.5 Pre-survey protocols

Before any electric fishing surveys are carried out, a number of administrative processes must be followed. Permission must be sought from relevant landowners, fishery owners and occupying angling clubs for access to a particular survey site. This should be carried out well in advance of surveys, as many angling clubs will only provide consent after a relevant meeting of their committee members. Access problems are generally only envisaged when external contractors are undertaking work, as the fishery interests are used to Environment Agency staff carrying out fisheries surveys. External contractors must be able to access any relevant databases on fisheries interests held by conservation agencies and environmental regulators.

"Consent to use fishing instruments (other than rod and line) and/or remove fish from inland waters" must be obtained from the Environment Agency in England and Wales before any electric fishing surveys. Application forms are available on the Environment Agency website (www.environment-agency.gov.uk) and these should be forwarded to the National Fisheries Laboratory at least 20 working days before the planned survey work. It is recommended in any application that surveyors apply for block consents covering a longer time period to allow for any delays in survey work due to inclement weather. For survey work in Scotland permission will have to be sought from the Scottish Executive, and in Ireland from the regional fisheries boards.

5 Sampling adult lamprey

While monitoring ammocoete populations provides a good opportunity to assess recruitment success and viability of the populations, consideration should also be given to supporting the condition assessment by monitoring adult population status where cost-effective methods are available. APEM

(2002) reviewed methods of sampling adult lamprey populations and recommended the following methods:

- Where feasible, counts of adult lamprey movements should be made at permanent salmonid fish traps and counters.
- Where available, video validation should be used to count the passage of lampreys over fish passes as a by-product of migratory fish movement validation procedures.

Anecodotal information about spawning areas should be collected from historical survey records, fishery bailiffs, inspectors, and ghillies, and efforts should be made to detect and record spawning activity at these sites during their routine activities from late March to mid-July each year. Where possible the condition of gravels around spawning areas should be assessed to account for any deterioration or siltation over time.

Counting of nests, proposed by APEM (2002), is not recommended as it is considered very unreliable. Similarly, concentrating sampling effort for ammocoetes immediately downstream of spawning areas is also not recommended as the juveniles appear to disperse quickly away from the spawning area after hatching, and optimal habitat for ammocoetes is not necessarily immediately below these sites.

However, every opportunity should be taken to record lamprey spawning behaviour, and river wardens, bailiffs, fisheries and conservation officers and the general public must be encouraged to report such events, along with a visual assessment of the status of the spawning gravel condition.

6 Assessing conservation status

Three strategies are proposed for assessment of conservation status of lamprey populations in SAC rivers.

6.1 Abundance classification

The first approach classifies the density of ammocoetes in order to establish the relative condition of fish populations in rivers. This assessment is based on two measures: the first a density estimate based on optimal habitat, and the second based on catchment-wide surveys that include a diversity of habitats. Output from the case studies on the rivers Eden and Teifi (Figure 2) showed that the mean density (± 95% confidence intervals) of lampreys in 48 sites (optimal and sub-optimal) was 6.6 (± 3.5) individuals m^{-2} in sub-optimal habitat and 31.9 (± 6.4) individuals m^{-2} in optimal habitat. This compares favourably with reported density estimates elsewhere in UK rivers (APEM 2001).

The targets for compliance with favourable conservation status are thus tentatively (conservatively) set at:

Optimal habitat

- Population density of river/brook lamprey ammocoetes >10 m^{-2}
- Population density of river/brook lamprey ammocoetes in chalk streams >5 m^{-2}
- Population density of sea lamprey ammocoetes 0.2 m^{-2}

Catchment perspective

- Population density of river/brook lamprey ammocoetes > 2 m^{-2}
- Population density of sea lamprey ammocoetes 0.1 m^{-2}

A lower abundance than these targets indicate rivers/reaches/sites in unfavorable condition. It is important that an appropriate number of sites are surveyed to account for natural spatial variation in lamprey population size in the SAC rivers under examination. Attention must also be paid to the role of barriers to migration that may influence the distribution of lamprey populations and affect the density of ammocoetes.

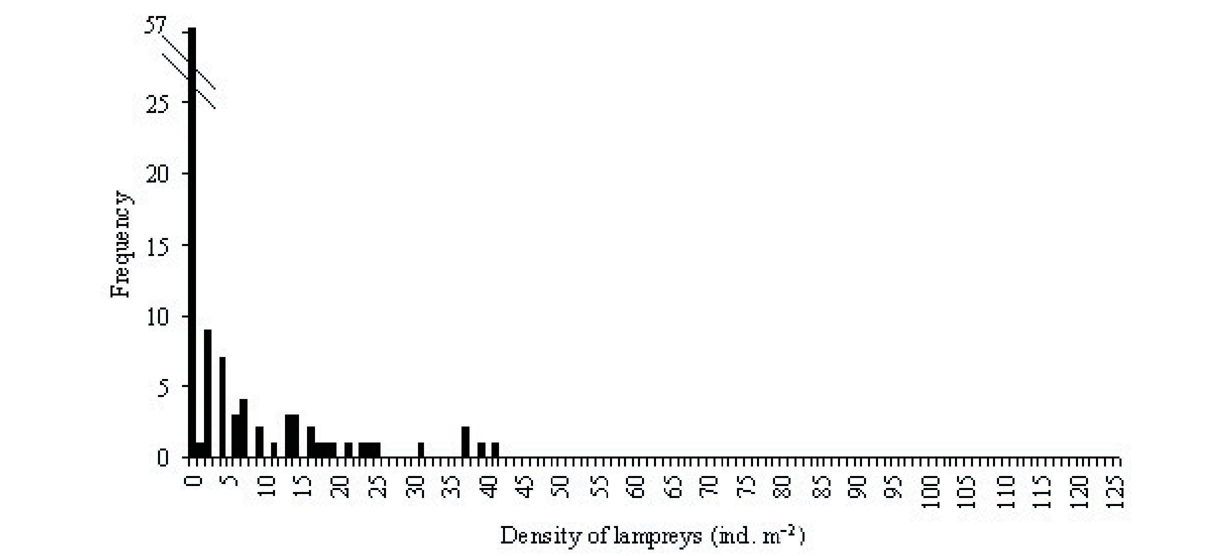

Figure 2. Distribution of densities of brook and river lamprey ammocoetes at individual sampling sites in the rivers Eden and Teifi.

6.2 Population demographic structure

A further assessment can be made of the demographic structure of the population (the contribution of different age-classes to the population) to demonstrate recruitment success. Output from the case studies on the rivers Eden and Teifi showed that where river and brook lamprey ammocoetes are locally abundant, at least two, and possibly up to six, age groups are present in the population (see Figure 3). Thus, to achieve favourable conservation status, where abundant, river and brook lamprey ammocoete populations should have at least two age-classes in the populations sampled from optimal habitat.

Deviation from compliance should not occur in more than one year in three. However, care must be taken when interpreting the output because of natural variability in river systems, and where possible the assessments should be made on individual rivers or sections of rivers.

6.3 Distribution

Further assessment of the status of lampreys can be derived from mapping their distribution in individual SAC rivers. Compliance with favourable conservation status should be recorded if there is no

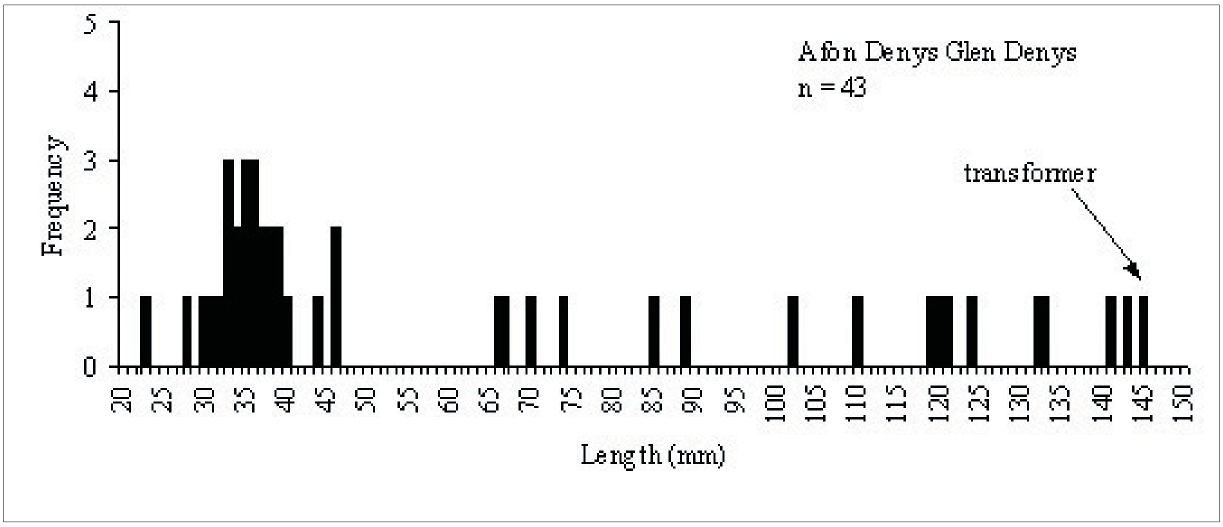

Figure 3. Length frequency distribution of river/brook ammocoetes at Glen Denys on the Afon Denys (Afon Teifi catchment).

decline in distribution of ammocoetes from the current, or where available, historical pattern. This distribution pattern should be linked to favourable habitat status, whereby no deterioration in habitat quality is registered. In particular river water quality should not be seen to deteriorate to any degree, if favourable status is to be recorded.

7 Case studies – the rivers Eden and Teifi

Two SAC rivers were chosen for testing the recommended monitoring programme; the rivers Eden and Teifi. Both rivers have good lamprey populations, well distributed throughout the catchment. Selection of suitable sites was based on discussion with Environment Agency fisheries and conservation officers and focused on sites used in the routine salmonid monitoring programme. The routine salmonid monitoring sites were chosen as they provided habitat for monitoring lamprey ammocoetes (optimal and sub-optimal) and had good access. In addition, one of the aims of the project was to assess the applicability of 'bolting on' lamprey surveys to existing Environment Agency monitoring programmes.

7.1 River Eden

7.1.1 Site selection

Forty sites on the River Eden were identified for testing of sampling strategies for ammocoetes. Twenty-five of the sites are routinely monitored by the Environment Agency on an annual basis, while the remaining 15 sites are sampled on a five-year rolling programme. Of the 40 sites selected permission was obtained to sample only 18 as Environment Agency staff were concerned that as the sites had recently been sampled for salmonids, local fishery and landowners would object to further surveys. The 18 sites were mainly situated in the south and west of the Eden catchment. Surveys were carried out in September 2002. Following further negotiations, permission was granted to survey a further 17 sites, which were due to be surveyed in mid- to late October, but imminent spawning of salmonids raised concerns in relation to possible damage, and subsequent heavy rainfall resulted in the surveys being abandoned for the season.

7.1.2 Sampling methodology

The sampling methodology followed the recommendations from the preliminary field trials carried out by APEM (2002) – electric fishing in $1m^2$ quadrats in optimal and sub-optimal habitat using depletion methodology (Section 3). However, early in the field trials it was apparent that this methodology was limited, so semi-quantitative sampling of sub-optimal habitat was also carried out.

7.1.3 Results

Details of the catches of ammocoetes in the River Eden are provided in Appendix 3, which documents density estimates (absolute values or adjusted density based on a catch efficiency of P = 0.58) and site parameters. It should be noted that identification of *Lampetra* ammocoetes to river or brook lamprey before transformation is not possible in the field using external characteristics (Gardiner 2003).

Lampetra ammocoetes were recorded at seven of the 18 sites sampled and were present in both optimal and sub-optimal conditions. No sea lamprey ammocoetes or transformers were recorded in the surveys, probably as a result of surveyors only being able to sample the upper part of the Eden catchment. Density of *Lampetra* ammocoetes ranged from 0.0 m^{-2} to 37.0 m^{-2} with a mean density of 3.7 ± 3.51 ind. m^{-2}. *Lampetra* ammocoetes were caught at all sites containing optimal habitat.

Lampetra ammocoete populations at the seven sites where they were recorded all showed signs of recruitment (0+ individuals), and the presence of a number of older ammocoetes before transformation. *Lampetra* transformers were caught at three of the sites (9, 13 and 15) where ammocoetes were recorded.

In summary, *Lampetra* ammocoetes were present at 39% of the sites surveyed on the River Eden, and at the majority of these sites there was evidence of recruitment (0+ individuals) and the presence of older age groups.

7.2 Afon Teifi

7.2.1 Site selection

Thirty-eight sites were identified in the Afon Teifi catchment for testing of sampling strategies for ammocoetes. Twelve of the sites are routinely monitored by the Environment Agency, while the remaining 26 sites are sampled on a five-year rolling programme. Obtaining permission to sample the sites proved problematic as there was little information available from any of the regulatory bodies on landowners, fishery owners and access rights. Hence, during the survey programme, permission was obtained by locating landowners directly, an often time-consuming process, which needs addressing in any future monitoring programme. The number of sites sampled was eventually reduced to 31 due to some being unsuitable (for example, too fast flowing for safe electric fishing) or permission to survey not being given by landowners. Surveys were carried out in October 2002.

7.2.2 Sampling methodology

The sampling methodology followed the recommendations from the preliminary field trials carried out by APEM (2002) – electric fishing in 1 m^2 quadrats in optimal and sub-optimal habitat using depletion methodology (Section 3). However, early in the field trials it was apparent that this methodology was subject to limitations, especially where optimal habitat was limited, so semi-quantitative sampling of sub-optimal habitat was also carried out.

7.2.3 Results

Details of the catches of ammocoetes in the Afon Teifi are provided in Appendix 4, which documents density estimates (absolute values or adjusted density based on a catch efficiency of P = 0.58) and site parameters. It should be noted that identification of *Lampetra* ammocoetes to river or brook lamprey before transformation is not possible in the field using external characteristics (Gardiner 2003).

Lampetra ammocoetes were recorded at 20 of the 31 sites sampled and were present in both optimal and sub-optimal conditions. One individual sea lamprey ammocoete was recorded in the surveys at Site 8, a tributary downstream of Cenarth Falls, which is thought to be a barrier to migratory lampreys. Density of *Lampetra* ammocoetes ranged from 0–191.0 individuals m^{-2} with a mean density of 23.7 ± 23.2 ind. m^{-2}. Optimal habitat was present at 10 of the sites sampled, but *Lampetra* ammocoetes were only found at six of these sites.

Variations in the age structure of *Lampetra* ammocoetes were found at the sampling sites. 0+ *Lampetra* ammocoetes were recorded at 12 sample sites, while the remaining eight sites contained >1+ *Lampetra* ammocoetes, possibly indicating poor recruitment in 2002 at these sites. *Lampetra* transformers were caught at seven of the sites (5, 8, 11, 15 18, 24 and 27) where lampreys were recorded.

In summary, *Lampetra* ammocoetes were present at 65% of the sites and *Petromyzon* ammocoetes at 0.03% of the sites surveyed on the Afon Teifi. At a number of sites there was evidence of recruitment (0+ individuals) and the presence of older age groups.

7.3 Assessment of number of sampling sites

During the surveys electric fishing efficiency was determined during a series of three catch-depletion estimates following the protocol outlined in Section 4.2. Electric fishing efficiency was similar in both rivers at P = 0.58 (± 0.04) for all river and brook ammocoetes. The number of samples that needed to be taken to obtain an accurate assessment of population density was derived using the procedure outlined in Section 4.2. The input parameters, based on 101 samples taken from the rivers Eden and Teifi, but combined as sampling in the Eden was restricted to a small part of the catchment, were as follows:

	Eden and Teifi
Number of sites surveyed	101
Cpop	46.37
CVNi	0.15
CV	0.16
Sampling variance	
K	3.00
P	0.58
N mean	6.61
Vn mean	0.98
CVNi	0.15

Based on these input parameters, the number of sites to be surveyed to obtain an accurate assessment of population density within Class 3 boundaries is approximately 100.

8 Survey programming

The proposed surveys for the SAC rivers can be broken down into three components: provisional fisheries assessment, fisheries index site monitoring and preliminary habitat/environmental assessment.

In the UK, any survey programme for condition assessment of lampreys in SAC rivers needs to use and build upon ongoing routine fisheries stock assessment work being undertaken by the Environment Agency and the Scottish and Northern Ireland fisheries boards and trusts. These organisations hold considerable data that should be used to formulate the survey programme. The costs of surveying individual SAC rivers for condition assessment of lampreys can be derived from an example of the time taken to sample the River Eden and Afon Teifi. It should be noted that the number of sites on which this analysis is based is not indicative of the actual number of sites that need to be sampled to achieve an accurate assessment (see section 4.3) of conservation status.

8.1 Timescale

Action	**Year of implementation**				
	1	**2–4**	**5**	**6–9**	**10**
Review of historical records for condition assessment.	*				
Assessment of habitat quality.	*				*
Monitoring of catchment-wide lamprey status.	*		*		*

8.2 Notes

1 Surveys are based on quantitative electric fishing using three persons. It is estimated that four sites per day can be sampled if distances between sites is short, access has been agreed and there is no restriction on working hours (i.e. overtime). It is anticipated that the time consuming component for lamprey ammocoete surveys will be the identification and measuring process, especially if sea lamprey ammocoetes are present in catches. A nominal 35 sites per river have been selected since this approximates to the number of sites needed to provide an accurate assessment of population status.

2 Costs for equipment, protective clothing, such as waders and wetsuit gloves, need to be considered, along with travel costs to and from survey sites.

8.3 Time taken

	Activity	Manpower support (person-days)
1	Annual monitoring of lamprey ammocoete populations in the River Eden (35 sites) (see note 1)	27
2	Annual monitoring of lamprey ammocoete populations in the Afon Teifi (35 sites) (see note 1).	27
3	Reporting and liaison meetings.	15

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Appendix 1. Survey report

Watercourse:						
Site name or identifier:						
National Grid Reference:						
Date and time sampled:						
Sampling methodology/equipment:				**Personnel:**		
Mean width (m):				**Length** (m):		
Mean depth (cm):				**Fished area** (m^2):		
Substrate %:	Mud	Sand	Gravel	Stones/cobbles	Boulder	Bedrock
Aquatic vegetation	Emergent	Floating	Submerged			
cover %:						
Bankside vegetation:	Left bank		Right bank			
Adjacent land use:	Left bank		Right bank			
Flow regime:						
Species details:						
Comments:						

Appendix 2. HABSCORE data input sheet

Site habitat record

Site identification	Site code	Catchment

Site name	NGR	River name	Survey date

Riparian shading of the site
What percentage of the water surface of the site is overhung by riparian vegetation? Estimate this percentage, for the three vegetation classes indicated, to the nearest 5%.

Deciduous trees & shrubs	Coniferous trees	Herbaceous vegetation

Migratory access

What is the accessibility of the site ?	Salmon	Sea trout
Always accessible		
Sometimes accessible		
Never accessible		

Substrate embeddedness
What is the degree of substrate embededdness throughout the site? Tick one box.

High		Medium		Low		

Flow conditions
Briefly describe the prevailing flow conditions (as observed at the time of the HABSCORE survey).

Upstream land-use considerations
What is the principal land-use immediately upstream of the site? Tick appropriate box(es).

Moor / heathland		Coniferous woodland		Deciduous woodland		Improved pasture	
Urban development		Rough pasture		Industrial land		Arable land	
Tips / waste		Other					

Potential impacts
Are there likely to be any impacts at the site from the following sources? Tick appropriate box(es).

pH effects		Stocking		Pollution		Migration barriers	
Habitat modification		River engineering		Low flows		Flow regulation	
Other							

Width and depth profile at bottom stop net
Record widths to the nearest 0.1m and depths to the nearest 1.0cm.

Channel width		
Depth at ¼ channel width		
Depth at ½ channel width		
Depth at ¾ channel width		

Section dimensions
Record section lengths and widths to the nearest 0.1 m and depths to the nearest 1 cm.

Section length									
Section width									
Depth at ¼ channel width									
Depth at ½ channel width									
Depth at ¾ channel width									

Substrate

Absent	Scarce	Common	Frequent	Dominant
0%	>0% & <5%	≤5% & <20%	≤20% & <50%	≤50%
A	S	C	F	D

What percentage of the stream bed area in each section is composed of the following substrate types? Enter A, S, C, F or D as appropriate (see above table).

Substrate category											
Bedrock/artificial											
Boulders >25.6 cm											
Cobbles 6.4-25.6 cm											
Gravel/coarse sand 0.2-6.4 cm											
Fine sand/silt <0.2 cm											
Compacted clay											

Flow

What percentage of the water surface area in each section is composed of the following flow types? Enter A, S, C, F or D as appropriate.

Flow category											
Cascade/torrential											
Turbulent/broken deep											
Turbulent/broken shallow											
Glide/run deep											
Glide/run shallow											
Slack deep											
Slack shallow											

Sources of cover for >10 cm trout

What percentage of the stream bed area in each section could provide cover (for a >10 cm trout) in the form of submerged overhang, or overhang within 0.5 m of the water surface? Indicate the abundance of cover within the various categories listed below. For 'submerged vegetation' include all macrophytes, mosses and algae providing cover. Estimate as 0, 1, 2, 3, 4, 5, 10, 15, 20, 25 ... 100%.

Source of cover										
Submerged vegetation										
Boulders, cobbles, etc.										
Tree root systems										
Branches and logs										
Undercut banks										
Other submerged cover										
Overhang within 0.5 m										
Area of deep water										

Appendix 3. Density estimates (m^{-2}) of lamprey in the River Eden catchment

River name	Site	Site no.	EA no.*	NGR	Sample	Area (m^2)	Density (m^{-2}) ± 95% CL	Habitat description	Habitat classification
Scandal Beck	Smardale	Site 1	1019	NY 735085	Set 1	1.0	0.00	5% silt (3 cm deep), 95% stones	Sub-optimal
					Set 2	1.0	0.00	5% silt (4 cm deep), 95% stones	Sub-optimal
Scandal	Soulby	Site 2	1020	NY 749109	Set 1	1.0	3.45	50% silt (9 cm deep), 50% stones	Sub-optimal
					Set 2	1.0	5.17	85% silt (9 cm deep), 5% stones	Sub-optimal
River Eden	Kirkby Stephen	Site 3	1006	NY 776089	Set 1	1.0	0.00	Bedrock, boulders, cobbles	No habitat
Swindale Beck	U/s Brough	Site 4	1027	NY 797147	Set 1	1.0	0.00	50% silt (5 cm deep), 50% gravel	Sub-optimal
					Set 2	1.0	0.00	50% silt (6 cm deep), 50% gravel	Sub-optimal
Carrock Beck	U/s of ford	Site 5	2324.8	NY 338350	Set 1	1.0	0.00	100% coarse gravel/cobbles	Sub-optimal
Park End Beck	Greenhead	Site 6	2330	NY 288371	Set 1	1.0	0.00	50% silt (4 cm deep), 50% gravel	Sub-optimal
					Set 2	1.0	0.00	25% silt (4 cm deep), 75% gravel	Sub-optimal
Park End Beck	Park	Site 7	2331	NY 301389	Set 1	1.0	0.00	50% silt (8 cm deep), 50% gravel	Sub-optimal
Park End Beck	Caldbeck	Site 8	2333	NY 323398	Set 1	1.0	0.00	50% silt (4 cm deep), 50% gravel	Sub-optimal
					Set 2	1.0	0.00	50% silt (4 cm deep), 50% gravel	Sub-optimal
Skirwith Beck	Playground	Site 9	1130	NY 617327	Set 1	1.0	37.0 ± 7.0	80% silt (10 cm deep), 20% org. material	Optimal
					Set 2	1.0	9.0 ± 0.42	80% silt (10 cm deep), 20% org. material	Optimal
					Set 3	1.0	25.86	85% silt (12 cm deep), 15% org. material Relative assessment without delimiting framework.	Optimal
River Eamont	Pooley Bridge	Site 10	1204	NY 471245	Set 1	1.0	0.00	70% silt (6 cm deep), 30% gravel	Sub-optimal
					Set 2	1.0	0.00	60% silt (8 cm deep), 40% gravel	Sub-optimal
					Set 3	1.0	0.00	75% silt (8 cm deep), 25% gravel	Sub-optimal
River Eamont	Bridge LHB	Site 11	N/a	NY 524287	Set 1	1.0	0.00	60% silt (7 cm deep), 40% gravel	Sub-optimal
River Eamont	Bridge RHB	Site 12	N/a	NY 524287	Set 1	1.0	1.72	80% silt (6 cm deep), 20% org. material	Sub-optimal
					Set 2	1.0	0.00	90% silt (5 cm deep), 10% gravel	Sub-optimal
					Set 3	1.0	0.00	90% silt (5cm deep), 10% cobbles	Sub-optimal
Crowdundle Beck	Millrigg bridge	Site 13	1069	NY 609281	Set 1	1.0	13.79	90% silt (25 cm deep), 10% org. material	Optimal
					Set 2	1.0	3.45	80% silt (15 cm deep), 20% org. material	Optimal
					Set 3	1.0	19.0 ± 8.0	80% silt (25 cm deep), 20% org. material	Optimal
River Lyvennet	Maulds Meaburn	Site 14	1056	NY 626164	Set 1	1.0	0.00	100% gravel	No habitat
Helm Beck	Little Ormside	Site 15	1034	NY 702166	Set 1	1.0	31.0 ± 0.0	80% silt (8 cm deep), 20% org. material	Sub-optimal
					Set 2	1.0	21.1 ± 0.26	80% silt (15 cm deep), 20% org. material	Optimal
Helm Beck	Cottage	Site 16	1033	NY 709149	Set 1	1.0	23.0 ± 0.0	85% silt (25 cm deep), 15% marginal grasses.	Optimal

River name	Site	Site no.	EA no.*	NGR	Sample	Area (m^2) 95% CL	Density (m^{-2}) ±	Habitat description	Habitat classification
Hilton Beck	Hilton	Site 17	1035	NY 732208	Set 1	0.09	0.00	Small area of gravel (7 cm deep)	Sub-optimal
					Set 2	0.09	0.00	Small area of gravel (6cm deep)	Sub-optimal
River Eden	Appleby	Site 18	1012	NY 683206	Set 1	1.0	1.72	100% sand (10 cm deep)	Sub-optimal
					Set 2	1.0	0.0	100% sand (12 cm deep)	Sub-optimal
					Set 3	1.0	3.45	100% sand (12 cm deep)	Sub-optimal

* = Environment Agency site identification number.

Appendix 4. Density estimates (m^{-2}) of lamprey in the Afon Teifi catchment

River name	Site	Site no.*	EA	NGR	Sample	Area (m^2)	Density (m^{-2}) ± 95% CL	Habitat description	Habitat classification
Nant Egnant	Tyncwm	1	TE 39	SN 769656	Set 1	1.0	0.00	50% gravel, 50% stones	Sub-optimal
Glasffrwd	Ford	2	TE 38	SN 752650	Set 1	1.0	0.00	10% silt(5 cm deep), 85% gravel, 5% organic material	Sub-optimal
					Set 2	1.0	0.00	5% silt (4 cm deep), 90% gravel, 5% organic material	Sub-optimal
					Set 3	1.0	0.00	5% silt (5 cm deep), 95% gravel	Sub-optimal
Afon Teifi	Pontrhydfen-digaid	3	TE 37	SN 730666	Set 1	0.5	7.00	50% silt (5 cm deep), 40% gravel, 10% organic material	Sub-optimal
Afon Groes	Cyrtau	4	TE 32	SN 702606	Set 1	1.0	10.34	8 cm of organic material on top of bedrock	Sub-optimal
					Set 2	1.0	8.62	80% silt (8 cm deep), 20% organic material	Sub-optimal
Afon Piliau	Glanpwllafon	5	TE 01B	SN 178437	Set 1	1.0	7.2 ± 0.52	95% silt (20 cm deep), 5% organic material	Optimal
					Set 2	1.0	3.45	90% silt (20 cm deep), 10% organic material	Optimal
					Set 3	0.25	13.79	50% silt (15 cm deep), 50% organic material. Relative assessment without delimiting framework.	Optimal
Afon Dyfan	Bridge above forest	6	TE 01	SN 216428	Set 1	1.0	0.00	100% silt (5 cm deep)	Sub-optimal
					Set 2	1.0	0.00	100% silt (5 cm deep)	Sub-optimal
					Set 3	1.0	0.00	100% silt (4 cm deep)	Sub-optimal
Afon Hirwaun	Ponthirwaun	7	TE 07#	SN 263452	Set 1	1.0	0.00	95% silt (15 cm deep), 5% organic material	Optimal
					Set 2	1.0	0.00	50% silt (30 cm deep), 50% organic material	Optimal
Afon Cych	Llettyclyd	8	TE 04	SN 270376	Set 1	1.0	1.72	100% silt (15 cm deep)	Sub-optimal
					Set 2	1.0	1.72		
							sea lamprey	80% silt (10 cm deep), 20% gravel	Sub-optimal
Afon Cych	Cwmorgan (d/s bridge)	9	TE 05	SN 292354	Set 1	1.0	0.00	50% silt (6 cm deep), 50% organic material	Sub-optimal
					Set 2	1.0	0.00	100% silt (5 cm deep)	Sub-optimal
					Set 3	1.0	0.00	100% silt (4 cm deep)	Sub-optimal
					Set 4	1.0	0.00	100% silt (4 cm deep)	Sub-optimal
Afon Mamog	D/s bridge	10	TE 05B#	SN 295362	Set 1	1.0	0.00	100% gravel (8 cm deep)	Sub-optimal
					Set 2	1.0	0.00	90% silt (10 cm deep), 10% organic material	Sub-optimal
Afon Berwyn	Brynhownant	11	TE 31	SN 694598	Set 1	1.0	5.17	95% silt (16 cm deep), 5% organic material	Optimal
					Set 2	1.0	13.4 ± 0.4	50% silt (16 cm deep), 20% gravel, 30% organic material	Sub-optimal
Afon Brenig	Tregaron (d/s sewage outfall)	12	TE 30	SN 677593	Set 1	1.0	39.0 ± 4.0	90% silt (10 cm deep), 10% organic material, 10 m d/s of sewage outfall	Sub-optimal
Afon Brefi	Llwyn	13	TE 22	SN 655552	Set 1	1.0	0.00	Cobbles/gravel	No habitat
Nant Clywedog	Llanfair Clydogau	14	TE 25a	SN 624511	Set 1	1.0	13.79	50% organic material on top of boulders/cobbles	Sub-optimal

River name	Site no.	Site	EA no.*	NGR	Sample	Area (m^2)	Density (m^{-2}) ± 95% CL	Habitat description	Habitat classification
Afon Granell	Capel-y-Groes	15	TE 20	SN 528483	Set 1	1.0	5.17	100% silt (6 cm deep)	Sub-optimal
					Set 2	1.0	13.0 ± 0.0	100% silt (6 cm deep)	Sub-optimal
Afon Granell	Maesllwyd	16	TE 21	SN 516509	Set 1	1.0	0.00	100% silt (15 cm deep)	Optimal
					Set 2	1.0	7.0	80% silt (10 cm deep), 20% organic material	Sub-optimal
					Set 3	1.0	0.00	75% silt (16 cm deep), 25% organic material	Optimal
Nant Creuddyn	Bridge off A482	17	TE 22B	SN 563498	Set 1	1.0	0.00	80% silt (10 cm deep), 20% organic material	Sub-optimal
					Set 2	1.0	17.24	60% silt (15 cm deep), 30% org.material, 10% subm. vegetatation	Optimal
Afon Denys	Glan Denys	18	TE 23	SN 582509	Set 1	1.0	41 ± 13	90% silt (30 cm deep), 10% organic material	Optimal
					Cathode	–	10 caught	Cathode placed in cattle drink for set 1 - 100% silt (20 cm deep)	Sub-optimal
Afon Dulas	Olwen	19	TE 23A	SN 579495	Set 1	1.0	0.00	100% sand (5 cm deep)	Sub-optimal
					Set 2	1.0	3.45	50% silt (10 cm deep), 50% submerged grasses	Sub-optimal
					Cathode	–	2 caught	Cathode placed in cattle drink for set 2 – 100% silt	Sub-optimal
								(10 cm deep)	
Afon Duar	Llanybydder	20	TE 19	SN 525444	Set 1	1.0	1.72	100% silt (5 cm deep) on top of gravel	Sub-optimal
					Set 2	1.0	0.00	10% silt (5 cm deep), 90% gravel	Sub-optimal
					Set 3	0.08	172.41	Small area of sloping mud/silt bank (60° angle) – 25 cm deep. No delimiting framework.	Sub-optimal
					Set 4	1.0	18.97	90% silt (20 cm deep), 10% organic material	Optimal
Nant Cledyn	Dre-fach	21	TE 17	SN 501459	Set 1	0.5	13.79	Relative assessment of three small areas of silt (5cm deep)	Sub-optimal
Nant Gwen	Aber Gwen	22	TE 14A	SN 443358	Set 1	1.0	0.00	10% sand (10 cm deep), 90% gravel	Sub-optimal
					Set 2	1.0	0.00	10% silt (5 cm deep), 90% gravel	Sub-optimal
					Set 3	1.0	0.00	10% silt (5 cm deep), 90% gravel	Sub-optimal
					Set 4	1.0	0.00	20% silt (5 cm deep), 80% gravel	Sub-optimal
Afon Talog	Blaenblodau bridge	23	TE 15	SN 463378	Set 1	1.0	0.00	50% sand (10 cm deep), 50% organic material	Sub-optimal
					Set 2	0.04	43.10	Small area of 50% sand (15 cm deep), 50% organic material. Relative assessment without delimiting framework	Optimal
Afon Cerdyn	Gwynionydd	24	TE 15A	SN 415421	Set 1	1.0	0.00	100% silt (10 cm deep)	Sub-optimal
					Set 2	0.09	191.37	Small area of 50% silt (15 cm deep) between tree roots. Relative assessment without delimiting framework.	Sub-optimal
					Set 3	1.0	0.00	100% silt (10 cm deep)	Sub-optimal

		no.	no.		no.	(m^2)	± 95 % CL		
Afon Ceri	U/s bridge	25	U/S of TE 08	SN 310429	Set 1	1.0	0.00	100% sand (20 cm deep)	Sub-optimal
					Set 2	1.0	0.00	50% silt (20 cm deep), 50% organic material	Optimal
					Set 3	1.0	0.00	95% silt (21 cm deep), 5% organic material	Optimal
Afon Ceri	Dolgain	26	TE 09#	SN 318445	Set 1	1.0	0.00	95% silt (20 cm deep), 5% organic material	Optimal
					Set 2	1.0	0.00	100% silt (14 cm deep)	Sub-optimal
Afon Banc	Aber-banc	27	TE 10#	SN 355418	Set 1	1.0	5.17	80% silt (15 cm deep), 20% organic material	Optimal
					Set 2	1.0	37.0 ± 0.0	60% silt (20 cm deep), 40% organic material/marginal grasses	Optimal
Afon Tyweli	Pen-y-banc	28	N/a	SN 443377	Set 1	1.0	13.79	Relative assessment of 50% silt (12 cm deep) in undercut bank (unable to place delimiting framework)	Sub-optimal
Nant Arbeth	Llechryd	29	TE 02	SN 219437	Set 1	1.0	17.24	50% silt (5 cm deep), 50% gravel	Sub-optimal
					Set 2	1.0	22.41	100% gravel covered with 5 cm layer of organic material	Sub-optimal
Afon Shedi	Industrial unit	30	U/s of TE 13	SN 392383	Set 1	3.0	0.57	No delimiting framework. Anode applied to small patches of silt and leaves	Sub-optimal
Afon Brefi	Craig Ifan – bridge	31	TE 28	SN 682546	Set 1	1.0	0.00	100% fine gravel (15 cm deep)	Sub-optimal
					Set 2	1.0	0.00	100% fine gravel (20 cm deep)	Sub-optimal

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The Life in UK Rivers project was established to develop methods for conserving the wildlife and habitats of rivers within the Natura 2000 network of protected European sites.

Set up by the UK statutory conservation bodies and the European Commission's LIFE Nature programme, the project has sought to identify the ecological requirements of key plants and animals supported by river Special Areas of Conservation.

In addition, monitoring techniques and conservation strategies have been developed as practical tools for assessing and maintaining these internationally important species and habitats.

River, brook and sea lamprey are found across Europe but are declining in many areas. They are vulnerable to a wide range of impacts, such as barriers to migration, pollution, and siltation of spawning gravels.

Lamprey are rarely the subject of intensive field research, so changes in population status cannot normally be detected early enough to prevent their decline.

This report suggests monitoring methods that can be used to determine whether river, brook and sea lamprey populations are in favourable condition, and what conservation action is necessary for their survival.

Information on Conserving Natura 2000 Rivers and the Life in UK Rivers project can be found at **www.riverlife.org.uk**

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