Monitoring the Bullhead

Cottus gobio

Conserving Natura 2000 Rivers

Monitoring Series No. 4

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Conserving Natura 2000 Rivers

This protocol for monitoring the bullhead (*Cottus gobio*) 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 European Union (EU) Habitats Directive (92/43/EEC) on Conservation of Natural Habitats and of Wild Fauna and Flora stipulates that EU member states maintain or restore habitats and species in a condition that ensures their favourable conservation status in the community. To comply with this directive, a number of rivers have been designated as Special Areas of Conservation (SACs) because they support important populations of vulnerable designated species. This report describes a standardised protocol to monitor bullhead stocks in SAC rivers to assess the conservation status of the species against a predetermined set of objectives.

A review of the bullhead's ecological and habitat needs (Tomlinson & Perrow 2003) concluded that the key features that dictate their distribution and abundance are: water depth, water velocity and substratum composition.

Bullhead condition assessment

Two strategies are proposed for assessment of favourable conservation status of bullhead populations in SAC rivers: abundance classification and population demographic structure.

Abundance classification

The first approach classifies the density of bullheads in order to establish the relative condition of fish populations in rivers. The target for favourable conservation status in upland streams is set at a conservative 0.2 individuals m^{-2}. Compliance in lowland rivers is set at an average adult relative population density above 0.5 individuals 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 bullhead population size in the SAC river under examination.

Population demographic structure

A further assessment can be made of the demographic structure of the population (the contribution of juveniles to the population to demonstrate recruitment success). To achieve favourable conservation status, where bullhead populations are abundant in discrete sections of a river, more than 40% of the individuals should be in the 0+ age class.

Deviation from compliance should not occur in more than one year in two, since populations have short life spans. 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 where discrete populations are known to exist.

Further assessment of the status can be derived from mapping the distribution of bullheads in individual SAC rivers. Favourable conservation status should be recorded if there is no decline in distribution from the current, or where available, historical pattern.

Monitoring strategy

Monitoring by electric fishing is recommended to provide an overview of the status of bullhead populations in SAC river catchments. A combination of quantitative (multi-run depletion method) and semi-quantitative (calibration method) sampling is recommended. Prior to undertaking fisheries surveys there is a need to ensure the appropriate access and fishing rights have been cleared. 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 in late summer so 0+ group bullheads are vulnerable to capture but do not dominate the catches. Annual surveys on index sites, the number of which is determined using statistical sampling designs, are recommended, and at least once 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. Outputs from the bullhead 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. These include a programme of monitoring based on contracting the work out to external consultants.

1 Introduction

Managing fish species of conservation value in SAC rivers 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.

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

- Favourable
- Unfavourable (with sub-categories 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 as to 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 portray 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 the bullhead (*Cottus gobio* L.) within SAC rivers. It is recognised that this process must be carried out under budgetary restrictions, so the protocols proposed are based on the minimum cost-effective strategies needed to provide information for accurate assessment of the species' status.

This report is divided into a number of sections. The first section reviews the biology and habitat requirements of the bullhead in order to identify the key parameters needed to 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 bullhead stocks in rivers and formulate the appropriate strategy. Finally, the mechanisms for establishing conservation targets for sustainability of specific stocks are described.

2 Ecology of the bullhead

The ecological requirements of the bullhead have been described in detail in the literature and reviewed by Tomlinson & Perrow (2003). The key features are described below.

The bullhead is widely distributed in England and Wales, but does not occur naturally in Scotland. The bullhead is benthic, nocturnal in habit and strongly territorial. It tolerates a wide range of climate and altitude, and occurs in waters ranging from high-altitude, nutrient-poor headwater streams to nutrient-rich lowland chalk streams (Mann 1971, Crisp *et al.* 1975). It has also been found in the shallower areas of large lakes (Mills & Mann 1983). The bullhead is typically found within riffle habitat in streams and small rivers, associated with firm gravel and sand substratum, and rarely on hard rock or mud (Smyly 1957; Mills & Mann 1983; Tomlinson & Perrow 2003). Habitat preferences for the bullhead were derived by Mangion-Horton (1997), and the important drivers appear to be substrate type, water velocity and water depth. These parameters vary for juvenile and adult components of the population.

The bullhead has a short life-cycle, with variations in growth rate, age of maturity and longevity. In lowland rivers, the bullhead reaches maturity after one year and there are usually three or four age classes in the population (Mills & Mann 1983, Perrow *et al.* 1997). In upland rivers, however, the bullhead generally reaches maturity later (three years) but is long-lived (Smyly 1957, Crisp *et al.* 1975). As a result, in southern chalk streams, 0+ age group bullheads account for 79–95% of the annual production (Mann 1971), whereas in the upland rivers, 0+ age group bullheads contribute only about 50% of the annual production. These differing life histories and reproductive strategies need to be taken into consideration when planning monitoring strategies for the bullhead in different SAC rivers. Of particular relevance is the high prevalence of 0+ individuals in the summer, which makes population assessment difficult.

One final issue that must be taken into account when undertaking condition assessment, is that the bullhead has a very limited home range, and genetically discrete populations exist in small sections of rivers or in individual tributaries (Bernd Hänfling, pers. comm.). Consequently, several distinct populations of bullheads may exist within each SAC river catchment and these do not genetically mix. This has serious ramifications for the conservation status of the bullhead in SAC rivers, as the stock in each river cannot necessarily be treated as one population that freely mixes.

3 Existing monitoring methods

Electric fishing is considered the best and most cost-effective sampling method for monitoring bullhead populations from a catchment-wide perspective. The results of electric fishing surveys provide a measure of distribution and abundance, and an assessment of the demographic structure of populations, identify adverse environmental impacts and, in extreme cases, highlight recruitment failures. However, such monitoring has rarely been used to provide statistically robust estimations of bullhead population size (quantitative stock assessment) in unit areas of streams, or an indication of relative population levels (qualitative catchment overview).

Preliminary field trials aimed to assess the habitat preference of the bullhead by investigating relative density in riffle, glide and pool habitats. Further investigations were carried out to assess the efficacy of sampling without stop-nets, as these are traditionally used in fish stock assessment exercises. The output of the field trials led to the following recommendations for bullhead monitoring:

- Sampling should be carried out by electric fishing 5–10 m riffle stretches in five runs for depletion estimates.
- Stop nets should not be used during sampling.
- To reduce the impact on juvenile development and avoid saturation of catches with 0+ fish, sampling should not be carried out before August.

Field testing of this methodology on the River Eden and Afon Teifi (Section 6) found that surveying 5–10 m riffle sections was only suitable when large densities of bullhead were present. From a total of 49 sites sampled in the two SAC rivers, only one site produced large numbers of bullhead from a section of riffle that was <10 m long.

At a considerable number of sites, between 10 to 30 m of river were required to obtain sufficient numbers of bullhead for population analysis. At sites where bullhead numbers were low or absent, lengths of riffles of up to 50 m were sampled in an attempt to assess accurately bullhead population characteristics or simply their presence or absence.

The proposed methodology for sampling bullhead populations also suggests quantitative depletion sampling (five runs) to provide estimates of absolute density based on the Carle & Strub (1978) Maximum Likelihood Model. Depletion sampling is fraught with difficulties related to catch efficiency, and this is compounded in the case of the bullhead, because its cryptic behaviour makes capture difficult. Bullheads are often immobilized *in situ* underneath stones and may be difficult to detect by survey operators. In addition, saturation of catches by 0+ juveniles can also result in inaccurate density estimates based on depletion sampling. Depletion estimates attempted on the two example SAC rivers often recorded greater catches of bullhead in the second and third runs than on earlier runs. This essentially contradicts one of the main assumptions of depletion sampling, that the population is reduced on each sampling run.

Furthermore, at sites where large numbers of 0+ individuals were captured, the first two runs in the depletion were often dominated by larger bullheads (>1+) while the later runs were dominated by 0+ bullheads. This is probably because of the difficulty in observing and catching 0+ bullheads in early runs when density of bullheads are high, with older, larger individuals being easier to observe. This latter finding results in increasing errors of depletion estimates. To overcome this problem, the number of sites that must be surveyed can be large, depending on the required precision. The use of depletion estimates was also found to be labour-intensive and time-consuming. Hence, carrying out five-catch depletion estimates on a large number of survey sites is not recommended, given financial and manpower limitations.

Qualitative and semi-quantitative sampling techniques, such as single-catch electric fishing, are less labour-intensive, and can be used to provide more information on the status of fish stocks in a catchment in terms of abundance, distribution and population structure, albeit at a lower level of precision. However, estimates of population size can be made if calibration exercises are carried out in conjunction with the qualitative surveys. Furthermore, for a catchment overview, high precision is not essential and such a semi-quantitative sampling method can provide cost-effective information on whether populations are above a minimum threshold relating to favourable or unfavourable status.

Calibration can be achieved by relating the semi-quantitative catch to sampling efficiency derived from multiple-catch depletion sampling carried out in similar habitat (see Cowx 1996). This method allows wider geographical coverage that reflects the character of a catchment, as more sampling sites can be surveyed each day. The main limitation of electric fishing for bullhead is that the method is restricted to wadeable streams, which means little information will be available for the larger, deeper main-stem rivers. It is thus recommended that semi-quantitative electric fishing, linked to gear calibration studies, is used for condition assessment of the bullhead in SAC rivers.

4 Sampling protocol

The following sampling protocol is proposed for the assessment of conservation status of the bullhead. The objective of the monitoring is to detect change in bullhead populations, determine conservation status and to allow appropriate management intervention. The sampling protocol can be 'bolted on' to existing monitoring programmes to maximise resource use and keep costs low.

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 discrete bullhead populations. Previous studies on all SAC rivers should enable fisheries scientists to establish, at least approximately, where the upper and lower limits of bullhead populations are within each SAC river. It is important that tributaries outside SAC boundaries are also sampled, as these may contribute significantly to the sustainability of bullhead populations in the SAC as a whole.

The sites selected must provide habitat coverage that encompasses all the life stages of the bullhead. The sites should include spawning habitat (coarse substrate with large stones), juvenile habitat (shallow stony riffles) and adult habitat (cover with the presence of large stones). The habitat preference of the bullhead is considered synonymous with habitat used by juvenile salmonids, which require riffle/pool sequences with the presence of boulders and cover. Thus, when selecting suitable sites for monitoring bullhead populations it is recommended that sites currently used for juvenile salmonid monitoring are reviewed for suitability. The use of existing monitoring sites has a number of advantages:

- Habitat requirements of the bullhead and juvenile salmonids are similar.
- Existing sites are usually well distributed through a particular SAC river catchment, and probably provide information on distribution of bullheads.

- Bullhead monitoring may be bolted on to current juvenile salmonid monitoring surveys, thus eliminating the need for separate surveys – a considerable saving to the monitoring agency.
- The presence/absence of bullheads is usually recorded in juvenile salmonid monitoring; hence, historical databases should be interrogated.
- Riparian owner and fishery owner access permissions are already agreed, thus avoiding lengthy discussions over access.

Since the bullhead has a variable life history strategy, depending on the location of the river (see Section 2), the frequency and timing of surveying is crucial to identify any trends in bullhead population status. Due to the bullhead's potentially short life cycle, it is recommended that surveys are carried out on an annual basis at index monitoring sites, using a mixture of quantitative and semi-quantitative sampling, to ensure speedy identification of any decline in population status. These surveys should be supplemented by more extensive coverage once every six years to comply with assessment reporting protocols. Index monitoring sites should be at locations on a particular catchment where bullheads are abundant and the population has a good demographic structure (there is a high proportion of 0+ fish in the population to evaluate recruitment success).

4.2 Number of sites and frequency of sampling

Before identifying possible mechanisms for studies defining whether a river is in favourable or unfavourable condition, it is important to consider the desired information with respect to individual bullhead 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 CV. The required precision in the stock estimate dictates the change in stock parameters that needs to be detected – that is, 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 high level of precision – a population change in time or space by a factor as small as 1.2 (for example, 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 CV not larger than about 0.05.

Class 2

Studies in this class require a high level of precision – a population change in time or space by a factor as small as 1.5 (for example, 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 CV not larger than about 0.10.

Class 3

Studies in this class require a high level of precision – a population change in time or space by a factor as small as 2.0 (for example, 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 bullhead 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 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 bullheads). The number of sites is determined from:

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

where C_{pop} is the spatial variation of population size among sites expressed as the coefficient of variation (standard deviation/mean) and $CV(N_i)$ is the within sites sampling error, expressed as the coefficient of variation (standard error/population size N_i) and CV precision class required expressed as standard error/mean (for purposes of bullheads 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 $CV(N_i)$ 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 6). 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 and Strub (1978) estimates (see Cowx 1983) was 0.60. Therefore CV_i using P = 0.60, number of removals k = 3 and an average population size N = 127 can be calculated as follows. The sampling variance is determined as:

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

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:

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

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

$$n = 92\,(0.68^2 + 0.024^2) / ((92 \times 0.16^2) + 0.68^2) = 15.11 = 15.$$

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 Eden and Teifi (Section 6). Such data probably do not exist for bullheads 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 the abundance of bullheads.

4.3 Sampling procedure

The use of electric fishing for sampling bullhead populations should follow a standard procedure to ensure comparison of data within and between rivers. This will allow identification of population trends between years and identify any improvement or decline in the population. The following sections detail the sampling protocol recommended for bullheads and its integration with existing routine monitoring programmes. The sampling protocol describes the procedures for assessment of an area of river to provide an indication of bullhead abundance and population structure (age and/or size). The sampling procedures are compatible with methodologies currently carried out in the UK, but ensure standardisation for comparative purposes.

4.3.1 Size of survey site

The methodology originally proposed for sampling of bullheads in SAC rivers was based on electric fishing 5–10 m riffles at each site using depletion sampling (APEM 2002). Field trials of this methodology on the River Eden and Afon Teifi identified many limitations and impracticalities of sampling only short lengths of riffles. In all but one survey, >10 m lengths of riffle needed to be sampled to obtain sufficient information on bullhead abundance and population structure. Sampling of 5–10 m riffles may be sufficient in lowland rivers (for example, the River Avon) where bullheads are abundant, but in upland rivers where bullhead densities are lower, longer lengths of river need to be sampled.

A two-tier approach to selection of survey length is recommended to tie-in with the lengths of rivers surveyed in routine salmonid monitoring. The lengths of rivers surveyed in routine salmonid monitoring programmes generally range between 30–100 m (for example, the River Eden: 30–80 m survey lengths and Afon Teifi: 42–56 m survey lengths).

It is recommended that in rivers where bullhead densities are high, 10–20 m lengths of river length are sampled. The site should be situated on a riffle upstream or downstream of the salmonid monitoring site.

However, in rivers where bullhead densities are low, it is recommended that the length of river surveyed should correspond to the length surveyed in routine salmonid monitoring programmes (all bullheads captured in the length of river surveyed for salmonids). In this scenario it is recommended that bullheads are collected at the same time as juvenile salmonids (or during the first electric fishing run if a multiple-catch depletion is being carried out).

The capture of bullheads following this protocol in relation to routine salmonid monitoring is likely to increase sampling time due to the increased effort employed in capturing bullheads, although this will probably be marginal where bullheads exist at low density. However, in reality, when carrying out any stock assessment on a length of river, all fish species immobilised should be captured and placed in suitable containers. Hence, bullheads should normally be captured as part of routine salmonid monitoring programmes. Under the current UK fisheries monitoring schemes, the UK Environment Agency provides abundance records of all fish species caught. Furthermore, the capture of every fish immobilised is critical to avoid repeated exposure to the electric field.

4.3.2 Timing of surveys

The timing of surveys for bullheads is important to reduce the problem of saturation of catches with 0+ individuals and the possible damage to juvenile development. Bullheads spawn between February and June and fractional reproduction is common in productive lowland rivers (Fox 1978). It is therefore recommended that bullhead monitoring surveys are carried out at the earliest in mid- to late August, and preferably in September or October. This recommendation, however, may have implications when carrying out the surveys as part of routine salmonid monitoring programmes.

Within the Environment Agency there are regional variations in the timing of salmonid surveys. For example, in 2002, juvenile salmonid surveys were carried out in the River Eden catchment between 8 July and 2 September and the Afon Teifi between 28 August and 17 September. The surveys carried out on the Eden in 2002, if incorporating bullhead surveys, may have resulted in saturation of catches with 0+ bullheads, while the surveys on the Teifi were during the recommended period. To solve this problem, each regional monitoring body may have to adjust part of its monitoring programme, although this may have implications in terms of manpower resources. This shift in timing of surveys must be balanced against potential curtailment of surveys due to inclement weather conditions and high flows.

4.3.3 Survey equipment and safety procedures

Electric fishing is the method recommended for sampling bullhead populations in SAC rivers. The technique is commonly used on a variety of waterbodies throughout the UK. Stringent guidelines for the design of gear, operation and safety regulations, produced by the Environment Agency and other fishery agencies in the UK, should be adhered to in all surveys (for example, the *Environment Agency Code of Practice for Safety in Electric Fishing Operations 2000*). Direct current (DC) or Pulsed Direct Current (PDC) should be used. Alternating current (AC) must not be used due to its damaging effect on fish.

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 kits) should meet the recommendations of the CEN directive (*CEN Directive for Water Analysis – Sampling of Fish with Electricity: Work Item 230116, revision of PrEN 14011, October 25, 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.

4.3.4 Sampling procedure

The methodology recommended for bullheads is calibrated sampling linked to semi-quantitative surveying of shallow riffles by electric fishing. The procedure is designed for use in wadeable rivers, as sampling bullheads in large, deep rivers is considered impractical. Multiple electric fishing of a known area of riffle is used to obtain absolute estimates of population density by an appropriate depletion model (for example, Carle & Strub or Zippin methods, see Cowx 1983) and derive the efficiency of the sampling effort or probability of capture (P). This sampling efficiency is then used for calibration against other sites where single-run electric fishing is carried out, and a relative measure of density (N individuals m^{-2}) is derived as ($N = P \times C$) where C is the total number of fish caught in one run of electric fishing (Cowx 1996).

Electric fishing can be carried out either using a bankside generator supply or back-pack gear. The waveform used should be DC or PDC, and the power output adjusted prior to surveying to maximise catch while minimising damage to fish. The length of river to be fished should be identified before surveying. This is critical if non-portable electric fishing gear is used to ensure sufficient lengths of anode cable are available. If sampling is part of a quantitative salmonid monitoring programme and stop nets are used, surveys should take place in an upstream direction from the lower stop-net to the upper stop-net. Where surveys are carried out without stop-nets, the length of river to be surveyed should be scrutinised to identify downstream and upstream limits of the survey site.

One or two anodes should be used depending on the width of river sampled and limitations on personnel. The anode should be operated in an upstream direction and should cover the wetted area of river ensuring adequate coverage of all available habitats. The anode must not be operated too close to the riverbed, as this may result in immobilization of bullheads in the substrate and make capture difficult. Each anode operator should be supported by two hand-netters (hand-net mesh size of 4 mm) who should have nets placed in the water column behind the anode. This is critical in the case of bullhead sampling, as immobilized juveniles may be swept rapidly downstream by the current, making them difficult to capture if the net is not placed immediately behind the anode.

Bullheads are often immobilized underneath or behind stones and their natural camouflage may make observation difficult, so extra effort may be required to capture bullheads in cryptic habitats. Polaroid glasses should be used to aid observation, this being especially important in sunny weather conditions.

Following capture, bullheads should be rapidly transferred to a suitable container carried by the hand-net operators. At the upstream limit of the survey area all stop switches should be activated and the electric fishing gear turned off (as per Environment Agency procedures) before the catch is processed. All sampling should be done in daylight hours.

Fish should be handled in ways that minimise damage due to handling and holding. In most cases aeration of water in the holding tank is essential for keeping caught fish in a good condition. Anaesthetic (benzocaine) should be used if the fish are to be handled for long periods. Whenever required, the equipment should be suitably disinfected after use, particularly if there is a risk of transferring alien species or pathogen agents.

4.3.5 Fish data collection

All bullheads captured (0+ juveniles and >1+ adults) should be measured (total length or fork length) to the nearest mm. If large numbers of bullheads are collected (for example, >100), a sub-sample of 100 individuals representative of the population structure should be measured and the remainder counted. The collection of this information is critical, as analysis of age structure of the sampled population will rely on assessment of length-frequency distribution. Fish should be handled in a way to minimise damage due to handling and holding, and aeration provided in the holding container to keep fish in good condition. Where there is the risk of transfer of alien species or pathogenic agents, equipment should be disinfected. All bullheads captured should be released at the site they were captured following completion of data collection.

4.3.6 Environmental monitoring

Environmental information should be collected on each sampling occasion. The primary information needed is listed in Table 1. In addition, a habitat survey of sampled reaches should be carried out every 10 years. Standard measurement procedures, such as those outlined in Bain & Stevenson (1999), and developed under the River Habitat Survey (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 the river where appropriate. Details of what constitutes favourable conservation status in relation to water quality, river morphology, flow, substrate and environmental disturbance are available on www.riverlife.org.uk.

4.4 Results and reporting

Reports should be prepared in which the results are presented as bullhead abundance, age structure and area of the sampling site. The report should include:

- **Species composition** as a list of caught species.
- **Abundance** of bullheads. This should be reported both as total recorded numbers and as numbers per m^2, 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, if such an estimate has been carried out.
- **Size and age 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.
- **External anomalies**. All fish should be checked for external anomalies and presence of parasites.

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 (for example, access problems, changes to site). An example of a baseline survey report form is given in Appendix 1, and the form for recording environment and habitat data for

Table 1. Environmental variables and data to be collected during bullhead monitoring 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 Global Positioning System or six-figure National Grid Reference)
Team (fishing staff leader and crew members)
Fishing method (wading upstream, boat)
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 (ring, anode diameter, number of anodes)
Use of stop-nets, when survey carried out in conjunction with salmonid survey (yes/no)
Number of removals
Site
Locality length (m)
Average width of wetted area (m)
Average depth (m)
Maximum depth (m)
Fished area (m^2)
Water current class (slow, intermediate, rapids and estimated current speed: $m\ s^{-1}$)
Substrate (dominating, subdominant)
Habitat type (pool, run, riffle, rapid)
Aquatic vegetation (missing, sparse, intermediate, species rich)
Dominating type of aquatic vegetation (submerged, floating, emergent)
Classification of surrounding riparian zone (urban, grazing, arable, forestry)
Shade
Large woody debris
Altitude
Stream gradient (slope in per thousand)
Secchi depth (m)
Habitat degradation
Photographic documentation (highly recommended)
Catch
Recorded species (common name and reference to scientific name)
Number of bullheads
Other species (presence or abundance)
Length of bullheads specimens (fork length to nearest mm)
External anomalies or parasites
The following details are optional:
Results from repeated samplings
Results on weight

determining conservation status 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 bullhead data. The Scottish Fisheries Coordination Centre database should be evaluated to ensure it is compatible with the Environment Agency database, and that information is transferable. Ownership and confidentiality of data may be an issue of importance and it is recommended that the conservation agencies, environmental regulators and fisheries interests develop a Memorandum of Understanding (MoU) regarding availability and usage 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 from relevant landowners, fishery owners and occupying angling clubs must be sought to gain 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 to speed up the process.

'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 named date period to allow for any delays in survey work due to inclement weather conditions. For survey work in Scotland permission will have to be sought from the Scottish Executive, and in Ireland from the Regional Fisheries Boards.

5 Assessment of conservation status

Two strategies are proposed for assessment of conservation status of bullhead populations in SAC rivers.

5.1 Abundance classification

The first approach classifies the density of bullheads in order to establish the relative condition of fish populations in rivers. Output from the case studies on the rivers Eden and Teifi (Figure 1) showed that the mean (± 95% confidence intervals) density of bullheads in 48 sites was 0.39 (± 0.31). This compares favourably with reported density estimates elsewhere in upland rivers in the UK (APEM 2001), thus the target for favourable conservation status in upland streams is initially set at a conservative 0.2 individuals m^{-2}. Compliance in lowland rivers is initially set at an average adult relative population density above 0.5 individuals 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 bullhead population size in the SAC river under examination.

5.2 Population demographic structure

A further assessment can be made of the demographic structure of the population (the contribution of

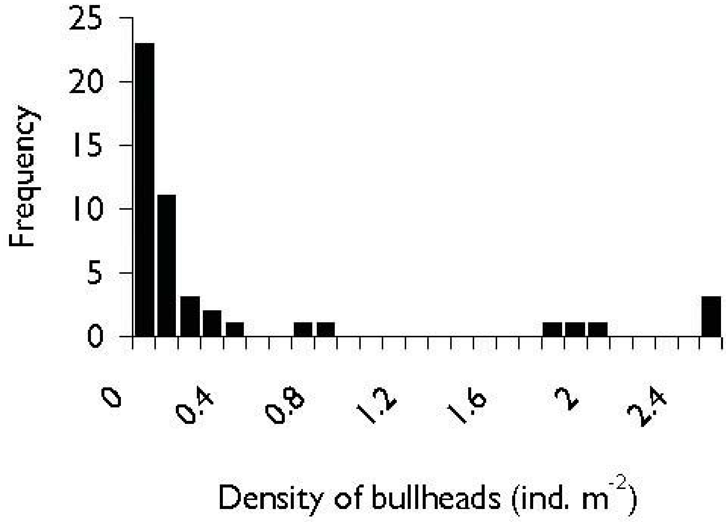

Figure 1. Distribution of densities of bullheads at individual sampling sites in rivers Eden and Teifi.

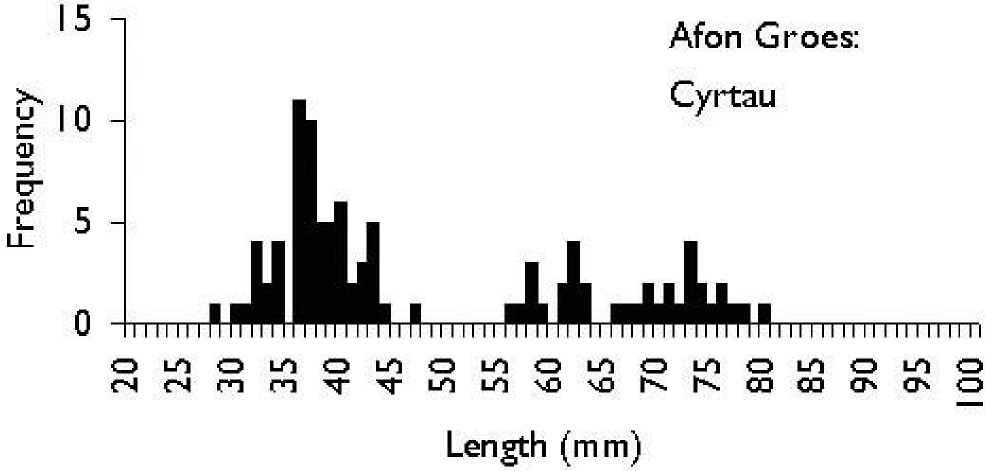

Figure 2. Length frequency distribution of bullheads at Cyrtau on the Afon Groes (Afon Teifi catchment) (n = 97).

juveniles to the population to demonstrate recruitment success). Output from the case studies on the rivers Eden and Teifi showed that where bullheads are locally abundant, juveniles contribute a high proportion of demographic structure of the population (see, for example, Figure 2). Thus, to achieve favourable conservation status, where abundant, bullhead populations in discrete sections of a river should have > 40% of the individuals in the 0+ age class.

Deviation from compliance should not occur in more than one year in two, since populations have short life spans. 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 river where discrete populations are known to exist.

Further assessment of the status of bullheads 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 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 and siltation of substrate, which leads to sub-optimal habitat for bullheads, should not have occurred to any degree, if favourable status is to be recorded.

6 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 bullhead 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 optimal habitat for monitoring bullheads (riffles) and had good access. The routine salmonid monitoring sites were also chosen because one of the aims of the project was to assess the applicability of bolting on bullhead surveys to existing Environment Agency monitoring programmes.

6.1 River Eden

6.1.1 Site selection

Forty sites on the River Eden were identified for testing of sampling strategies for bullheads. 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 groups and landowners would object to further surveys. Unfortunately, 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.

6.1.2 Sampling methodology

The sampling methodology followed the recommendations from the preliminary field trials carried out by APEM (2002) – electric fishing 5–10 m riffle samples using depletion methodology (Section 3). However, early in the field trials it was apparent that this methodology was subject to limitations and >10 m lengths were usually surveyed to obtain a better sample of bullheads.

6.1.3 Results

Details of the catches of bullheads in the River Eden are provided in Appendix 3, which documents density estimates and site parameters. Lengths of river sampled at sites ranged between 7.8 m (Site 11) and 40.0 m (Site 5), and mean river width ranged between 1.6 m (Site 6) and 12.5 m (Site 1). Bullheads were recorded at 12 of the 18 sites sampled and were present in both optimal and sub-optimal conditions. Density of bullheads ranged from zero to 3.31 m^{-2} with a mean density of 0.52 ± 0.47 m^{-2}. At two of the sites where bullheads were absent, habitat conditions were deemed optimal and there was no apparent reason for their absence. At the remaining four sites where bullheads were absent, conditions were considered sub-optimal.

Bullhead populations at the 12 sites where they were recorded all showed signs of recruitment (0+ individuals, <50 mm) and the presence of adult spawning stock (>1+, >50 mm). Sites that contained high densities of bullheads (sites 1, 2 and 18) were dominated by 0+ individuals indicating good recruitment. However, at Site 9 the reverse was true, with low numbers of 0+ individuals compared with adults. The reason for the latter case is unclear but may indicate poor spawning grounds or the nursery areas for this tributary being situated elsewhere. In summary, bullheads were present at 67% of the sites surveyed on the River Eden, and at these sites there was evidence of recruitment and an adult spawning stock.

6.2 Afon Teifi

6.2.1 Site selection

Thirty-eight sites were identified in the Afon Teifi catchment for testing of sampling strategies for bullheads. 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 that 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.

6.2.2 Sampling methodology

The sampling methodology followed the recommendations from the preliminary field trials carried out by APEM (2002) – electric fishing 5–10 m riffle samples using depletion methodology (Section 3). However, early in the field trials it was apparent that this methodology was subject to limitations and >10 m lengths were usually sampled to obtain a better sample of bullheads.

6.2.3 Results

Details of the catches of bullheads in the Afon Teifi are provided in Appendix 4, which documents density estimates and site parameters. Lengths of river sampled at the sites ranged between 8.8 m (Site 13) and 53.4 m (Site 28), and mean river width ranged between 1.7 m (Site 10) and 9.1m (Site 3). Bullheads were recorded at 13 of the 31 sites sampled and were present in both optimal and sub-optimal conditions.

Density of bullheads ranged from zero to 5.79 m^{-2} with a mean density of 0.44± 0.43 m^{-2}. At seven of the sites where bullheads were absent, habitat conditions were deemed optimal and there was no apparent reason for their absence. At the remaining 11 sites where bullheads were absent conditions were considered sub-optimal. Bullhead populations at 12 of the 13 sites where they were recorded showed signs of recruitment (0+ individuals, <50 mm) and the presence of adult spawning stock (>1+, >50 mm). The bullhead population at site 31 showed an absence of 0+ individuals, possibly indicating the absence of suitable spawning or nursery habitat in the locality.

The four sites that contained high densities of bullheads (sites 4, 11, 13 and 19) revealed variations in the dominance of 0+ and >1+ individuals, in contrast to that found on the River Eden (Section 6.1.3). Sites 4 and 19 were dominated by 0+ individuals, while sites 11 and 13 were dominated by >1+ individuals, possibly indicating that the latter had limited suitable spawning or nursery habitat.

In summary, bullheads were present at 42% of the sites surveyed on the Afon Teifi, and at the majority of these sites there was evidence of recruitment and an adult spawning stock.

6.3 Assessment of number of sampling sites

During the surveys electric fishing efficiency was determined during a series of five-catch depletion estimates following the protocol outlined in Section 4.2. Electric fishing efficiency was similar in both rivers at P = 0.31 (± 0.04) for all size groups and P = 0.36 (± 0.04) for >0+ age group individuals. Although sampling efficiency was slightly higher for >0+ group fish, differences were not considered sufficiently great to warrant sampling based on discrimination of size groups. The number of sampling sites that need to be sampled to obtain an accurate assessment of population density was derived using the procedure outlined in Section 4.2. The input parameters were as follows:

	Eden	Teifi
Number of sites surveyed	18	31
Cpop	1.77	3.06
CVNi	1.23	1.19
CV	0.16	0.16
Sampling variance		
K	5	5
P	0.31	0.31
Nmean	0.53	0.44
Vnmean	0.41	0.35
CVNi	1.23	1.34

Based on these input parameters the number of sites to be surveyed to obtain an accurate assessment of population density within Class 3 boundaries on the River Eden was 24 and on the Afon Teifi 34.

7 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. Any survey programme for condition assessment of bullheads 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 board/trusts. These organisations hold considerable data that should be used to formulate the survey programme.

Timescale

Action	Year of implementation				
	1	2–5	6	7–11	12
Review of historical records for condition assessment	*				
Assessment of habitat quality	*				*
Monitoring of catchment-wide bullhead status	*		*		*
Monitoring of index sites	*	*	*	*	*

Manpower

Activity	Person-days
1 Annual monitoring of bullhead populations in the River Eden (23 sites)	15
2 Annual monitoring of bullhead populations in the Afon Teifi (35 sites)	21
3 Reporting and liaison meetings	15
Total	**51**

Note: Surveys are based on quantitative and semi-quantitative electric fishing using three people. It is estimated that five sites (one quantitative and four semi-quantitative) per day can be sampled if distances between sites is short, access has been agreed and there is no restriction on working hours (that is, overtime). Note that the survey team only supplies technical assistance. If senior technical support is required the costs will be higher.

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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 bullheads in the River Eden catchment.

River name	Site name	Site no.	EA ID no*	NGR	Density ± 95% CL	Survey length (m)	Mean width (m)	Habitat description and dominant substrate	Habitat classification
Scandal Beck	Smardale	1	1019	NY 735085	0.73 ± 0.21	13.7	12.5	Riffle, cobbles/gravel	Optimal
Scandal Beck	Soulby	2	1020	NY 749109	1.83 ± 0.66	10.1	8.5	Riffle, cobbles/gravel	Optimal
River Eden	Kirkby Stephen	3	1006	NY 776089	0.32 ± 0.06	11.8	9.2	Riffle, bedrock, boulders	Sub-optimal
Swindale Beck	U/s of Brough	4	1027	NY 797147	0.00	25.0	3.9	Riffle, boulders, cobbles/gravel	Optimal
Carrock Beck	U/s of ford	5	2324.8	NY 338350	0.00	40.0	4.1	Cascade/pool, boulders, cobbles	Sub-optimal
Park End Beck	Greenhead	6	2330	NY 288371	0.00	25.0	1.6	Riffle/pool, cobbles/gravel	Sub-optimal
Park End Beck	Park End	7	2331	NY 301389	0.00	35.0	4.6	Riffle, cobbles/gravel	Optimal
Park End Beck	Caldbeck	8	2333	NY 323398	0.005	25.0	7.9	Riffle, cobbles/gravel	Optimal
Skirwith Beck	Playground	9	1130	NY 617327	3.31 ± 0.29	12.1	2.3	Riffle, cobbles/gravel	Optimal
River Eamont	Pooley Bridge	10	1204	NY 471245	0.16 ± 0.00	17.1	6.6	Riffle, gravel/cobbles	Optimal
River Eamont	Bridge LHB	11	N/a	NY 524287	0.13 ± 0.00	7.8	8.8	Fast flowing riffle, cobbles/gravel	Optimal
River Eamont	Bridge RHB	12	N/a	NY 524287	0.04	11.4	4.9	Riffle, cobbles/sand/gravel	Sub-optimal
Crowdundle Beck	Millrigg bridge	13	1069	NY 609281	0.09	18.2	4.1	Riffle, cobbles/gravel	Optimal
River Lyvennet	Maulds Meaburn	14	1056	NY 626164	0.49 ± 0.05	17.5	4.2	Riffle, cobbles, nutrient enrichment	Optimal
Helm Beck	Little Ormside	15	1034	NY 702166	0.02	22.0	4.9	Riffle, cobbles/gravel	Optimal
Helm Beck	Cottage	16	1033	NY 709149	0.00	19.7	4.2	Pool/riffle, cobbles/boulders	Sub-optimal
Hilton Beck	Hilton	17	1035	NY 732208	0.00	30.0	2.5	Cascade/pool, cobbles/bedrock	Sub-optimal
River Eden	Appleby	18	1012	NY 683206	1.77 ± 0.59	13.6	6.1	Riffle (LHB), cobbles/gravel	Optimal

Appendix 4. Density estimates (m^2) of bullheads in the Afon Teifi catchment

River name	Site name	Site no.	EA ID no*	NGR	Density ± 95% CL	Survey length (m)	Mean width (m)	Habitat description and dominant substrate	Habitat classification
Nant Egnant	Tyncwm	1	TE 39	SN 769656	0.00	11.3	3.3	Riffle, cobbles/gravel	Optimal
Glasffrwd	Ford	2	TE 38	SN 752650	0.00	18.3	5.8	Riffle/glide, boulders/cobbles	Sub-optimal
Afon Teifi	Pontrhydfendigaid	3	TE 37	SN 730666	0.00	12.1	9.1	Riffle, cobbles/gravel	Optimal
Afon Groes	Cyrtau	4	TE 32	SN 702606	2.72 ± 0.61	12.4	3.7	Riffle, cobbles/gravel	Optimal
Afon Piliau	Glanpwllafon	5	TE 01B	SN 178437	0.00	11.2	2.3	Riffle/pool, cobbles/gravel	Sub-optimal
Afon Dyfan	Bridge above forest	6	TE 01	SN 216428	0.00	28.0	3.2	Riffle, cobbles/gravel but compacted and silt covered	Sub-optimal
Afon Hirwaun	Ponthirwaun	7	TE 07#	SN 263452	0.00	27.5	2.7	Riffle/glide, cobbles/bedrock	Sub-optimal
Afon Cych	Llettyclyd	8	TE 04	SN 270376	0.00	26.6	6.6	Riffle, cobbles/gravel	Optimal
Afon Cych	Cwmorgan (d/s bridge)	9	Nr TE 05	SN 292354	0.00	35.8	4.5	Riffle, cobbles/ gravel/ boulders	Optimal
Afon Mamog	D/s bridge	10	TE 05B#	SN 295362	0.00	24.0	1.7	Riffle/glide, cobbles/gravel boulders	Sub-optimal
Afon Berwyn	Brynhownant	11	TE 31	SN 694598	1.91 ± 0.51	14.5	4.1	Riffle, cobbles/gravel	Optimal
Afon Brenig	Tregaron (d/s sewage outfall)	12	NrTE 30	SN 677593	0.25 ± 0.01	14.5	3.6	Riffle/glide, cobbles/ boulders, silt accummulation	Sub-optimal
Afon Brefi	Llwyn	13	TE 22	SN 655552	2.51 ± 0.37	8.8	6.1	Riffle, cobbles/gravel	Optimal
Nant Clywedog	Llanfair Clydogau	14	TE 25a	SN 624511	0.00	24.0	2.0	Riffle, cobbles/gravel	Optimal
Afon Granell	Capel-y-Groes	15	TE 20	SN 528483	0.04	27.3	3.4	Riffle/glide, cobbles/gravel	Sub-optimal
Afon Granell	Maesllwyd	16	TE 21	SN 516509	0.06	24.1	4.9	Riffle, cobbles/boulders	Sub-optimal
Nant Creuddyn	Bridge off A482	17	TE 22B	SN 563498	0.07	19.6	4.1	Glide, cobbles	Sub-optimal
Afon Denys	Glan Denys	18	TE 23	SN 582509	0.30 ± 0.07	20.3	3.4	Riffle/glide, cobbles, silt accumulation, sewage fungus	Sub-optimal
Afon Dulas	Olwen	19	TE 23A	SN 579495	5.79 ± 1.06	11.0	3.8	Riffle, cobbles/gravel	Optimal
Afon Duar	Llanybydder	20	TE 19	SN 525444	0.03	36.4	5.1	Riffle, cobbles/gravel	Optimal
Nant Cledyn	Dre-fach	21	TE 17	SN 501459	0.10 ± 0.00	25.0	5.5	Riffle, cobbles/gravel	Optimal
Nant Gwen	Aber Gwen	22	TE 14A	SN 443358	0.00	31.5	1.9	Riffle/glide, cobbles/gravel	Sub-optimal
Afon Talog	Blaenblodau	24	TE 15A	SN 415421	0.00	30.0	4.6	Glide, cobbles	Sub-optimal
Afon Ceri	U/s bridge	25	u/s TE 08	SN 310429	0.00	38.4	5.8	Riffle, cobbles/bedrock	Sub-optimal
Afon Ceri	Dolgain	26	TE 09#	SN 318445	0.00	27.5	5.1	Riffle, cobbles/gravel	Optimal
Afon Banc	Aber-banc	27	TE 10#	SN 355418	0.00	40.0	2.9	Glide, cobbles	Sub-optimal
Afon Tyweli	Pen-y-banc	28	N/a	SN 443377	0.00	53.4	5.3	Riffle, cobbles	Sub-optimal
Nant Arbeth	Llechryd	29	TE 02	SN 219437	0.05	36.1	3.2	Glide, cobbles	Sub-optimal
Afon Shedi	Industrial unit	30	u/s TE 13	SN 392383	0.00	30.0	3.6	Riffle, cobbles/gravel	Optimal
Afon Brefi	Craig Ifan bridge	31	TE 28	SN 682546	0.06	31.4	4.5	Riffle/pool, cobbles/boulders	Sub-optimal

Conserving Natura 2000 Rivers

Ecology Series

1 Ecology of the White-clawed Crayfish, *Austropotamobius pallipes*
2 Ecology of the Freshwater Pearl Mussel, *Margaritifera margaritifera*
3 Ecology of the Allis and Twaite Shad, *Alosa alosa* and *A. fallax*
4 Ecology of the Bullhead, *Cottus gobio*
5 Ecology of the River, Brook and Sea Lamprey, *Lampetra fluviatilis*, *L. planeri* and *Petromyzon marinus*
6 Ecology of Desmoulin's Whorl Snail, *Vertigo moulinsiana*
7 Ecology of the Atlantic Salmon, *Salmo salar*
8 Ecology of the Southern Damselfly, *Coenagrion mercuriale*
9 Ecology of the Floating Water-plantain, *Luronium natans*
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These publications can be obtained from:

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They can also be downloaded from the project website: www.riverlife.org.uk

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.

The bullhead is a distinctive species with unique behaviour among fish, ranging from male parental care to sound production. It is also a good indicator of the naturalness of streams.

Although it is widespread throughout Europe, the bullhead is vulnerable to a range of impacts, such as increased siltation, channel modification and water pollution.

This report suggests monitoring methods that can be used to determine whether bullhead 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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