Monitoring the Atlantic Salmon

Salmo salar

Conserving Natura 2000 Rivers

Monitoring Series No. 7

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Conserving Natura 2000 Rivers

This protocol for monitoring the Atlantic salmon (*Salmo salar*) 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 favourable conservation status. To comply with this directive, a number of rivers have been designated Special Areas of Conservation (SACs) because they support important populations of vulnerable qualifying species. This report describes a standardised protocol to monitor salmon stocks in SAC rivers to assess the conservation status of the species against a predetermined set of objectives.

The approach to condition assessment and monitoring is outlined below:

Stock characterisation

The first issue to address before considering an overall strategy to evaluate the condition of salmon in an SAC is to identify all biologically significant units or discrete stocks within the catchment. These require to be monitored and managed separately and may be characterised by salmon exhibiting distinctive run-timing, or life history strategy which may also be associated with a particular spatial element of the catchment – for example, a particular tributary. Such stocks should initially be identified by run-timing as indicated by counter and catch data in various parts of the catchment, ideally collaborated by tagging and or genetic studies. This is particularly important given that some salmon SACs have been designated for the diversity of stocks within the catchment.

A review of the salmon's life cycle and habitat needs concluded that the key life stages where salmon can be monitored are:

- Adult run (numbers, size, timing and age composition) based on upstream trap and counter data or, where not available, rod and net catch statistics.
- Density of juveniles based on a mixture of quantitative and semi-quantitative electric fishing surveys. The adoption of smolt trapping should also be considered. The conservation status of each life stage should be assessed against defined reference points.

Adult salmon condition assessment

Population conservation limits

One of the objectives of salmon conservation and fisheries management is to develop a practical basis for managing individual salmon stocks and the environment in which they live in order to optimise recruitment. To achieve this, various stock and fishery reference points are set, including spawning escapement and egg deposition. The conservation limit is a recognised standard accepted by the North Atlantic Salmon Conservtion Organization (NASCO) and can be calculated from an assessment of the capacity of the river network (the whole catchment) to generate smolts from spawning and juvenile-rearing habitat under conditions of high environmental quality (not necessarily existing quality).

The procedure proposed uses the principle of setting conservation limits to maximise egg deposition, and determines the fish counter or rod catch equivalent against which compliance is assessed. Although conservation limits are currently calculated at the level of the entire catchment, it is proposed that, on SAC rivers individual conservation limits are derived and applied to each biologically significant unit or stock that can be identified. To achieve favourable status the adult run as measured by counters and/or catches must exceed the annual spawning escapement equivalent in any of four years over a five-year period.

Juvenile salmon condition assessment

Parr and fry

Bearing in mind the current paucity of smolt traps, monitoring of earlier life stages by electric fishing is likely to continue to be the key juvenile assessment methodology. Additionaly, electric fishing of fry and parr can provide finer scale spatial information on the stock, this being important for managent and assessment purposes.

To make a condition assessment of juvenile population status two approaches are recommended:

Optimum utilization model: The first approach is to relate the observed juvenile densities to densities that would be expected under conditions of high environmental quality. The intrinsic capacity of rivers to support salmon juveniles varies from river to river and reach to reach, such that a uniform target is inappropriate. 'Reference' densities for any monitoring site on a salmon river can be generated by the HABSCORE model or a derivative. The HABSCORE predictions are useful for compliance testing because a score of habitat quality identifies locations where the population is below the expected level as a result of degraded and/or changing habitat conditions, and a score of habitat utilisation indicates where there is failure in the recruitment process.

As a rough guide, a reporting unit might be said to be in favourable condition when the confidence intervals around at least 80% of Habitat Utilisation Index scores generated within the reporting period encompass unity.

Abundance classification: The second approach classifies the density of juvenile salmon in order to establish the relative condition of fish populations in rivers. Appropriate absolute classification values that correspond to favourable condition will have to be developed, although compliance with a high-density classification category clearly suggests the population is in good condition, whereas low grading highlights rivers/reaches/units/sites in unfavourable condition. This approach should only be adopted as an interim approach until HABSCORE data are available for the monitoring site, thus enabling the optimum utilization model approach to be adopted.

Smolts

A measure of numbers of outward migrating smolts is the most valuable information on early life stage of salmon populations. Not only does it provide an unambiguous measure of the freshwater status of the population for any given year, but data on the return of these smolts as adults (from counter or rod catch data) allows sea survival to be calculated. Critically, the relative contribution of environmental conditions in freshwater versus the sea to the condition of the population can thus be determined.

Although somewhat costly to install and run, consideration should be given to installing smolt counting facilities on SAC rivers where this is technically feasible. Targets for freshwater smolt output will need to be developed about which judgements of condition status can be made.

Juvenile monitoring strategy

For electric fishing, a combination of semi-quantitative (calibration, timed (5 min)) and quantitative (multi-run depletion method) sampling is recommended.

A two-phase monitoring strategy is recommended comprising:

- A catchment-wide, fine resolution (every 1.5 km) survey, based on semi-quantitative (5-min. timed) electric fishing. This will enable a catchment-wide comparison in a single year, as well as pinpointing areas of poor recruitment where management can be targeted.
- A rolling programme (no less frequently than three-year periodicity) of quantitative sites to assess specific geographical stocks.

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 and where possible European Standards Committee (CEN) standards. Standard data recording forms are recommended for reporting fisheries and environmental data. The data input forms for HABSCORE are recommended for recording environmental and physicochemical data. Surveys should be conducted when young-of-the-year fry are vulnerable to capture. This will be during the summer months although the most appropriate times will be determined by altitude and latitude. Surveys should therefore start at the bottom end of catchments and work upstream, to allow for a longer working season.

Standard reporting procedures used by the appropriate agencies in each country will be used. It is recommended 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 adult and juvenile salmon surveys will be interpreted in relation to compliance with favourable condition. Reasons for failure will be determined from environmental and physiochemical data collected parallel to the fisheries surveys.

1. Introduction

The Habitats Directive stipulates that 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 Special Areas of Conservation (SACs) because they support important populations of vulnerable designated species. Conservation objectives have been established in the UK for SACs by the conservation agencies, in collaboration with the Environment Agency, about which judgements of favourable condition will be made. These conservation objectives will be the basis of environmental objectives for SACs under the Water Framework Directive(2000/60/EC).

To manage the salmon stocks in SAC rivers against a set of conservation objectives requires a monitoring programme that will establish the status of the species against the predetermined conservation objectives – a process known in the UK as 'condition assessment'. Condition assessment 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 four categories:

- Favourable
- Unfavourable
  - Declining
  - Maintained
  - Recovering
- Partially destroyed
- Destroyed.

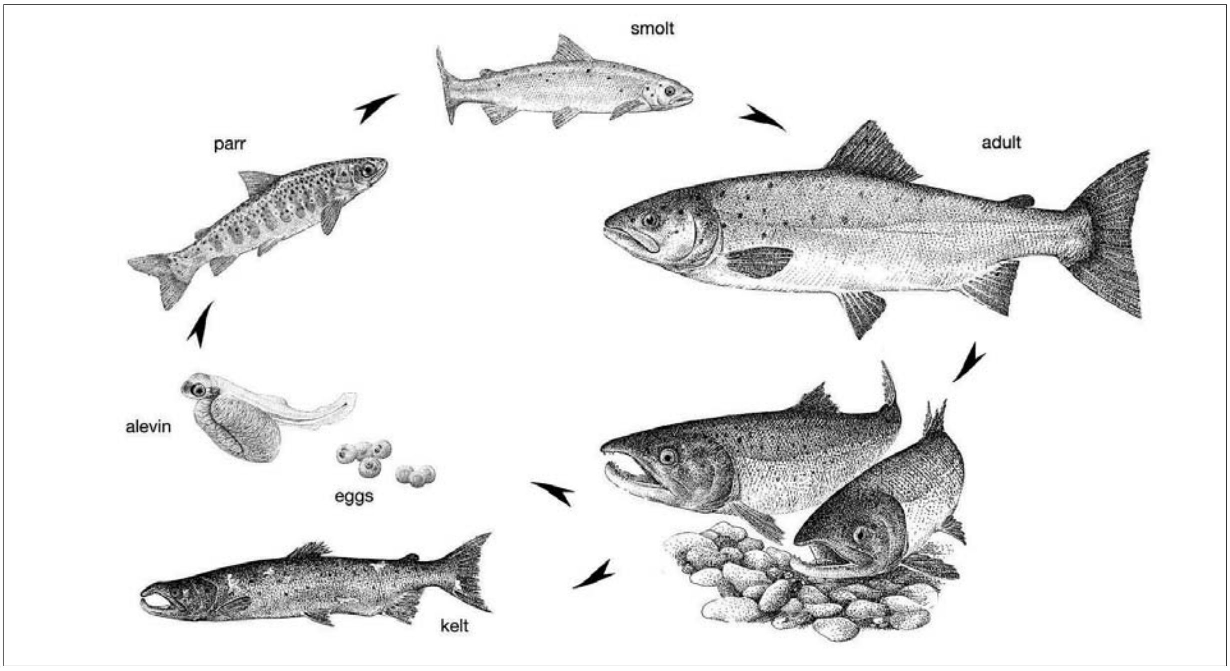
The condition assessment must provide information on the present status of the species and give at least a broad indication as to trends. Sampling strategies must therefore be able to detect any change over a period of years or differences between sites. The ability to compare different sites is important 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 Atlantic salmon (*Salmo salar* 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 species status.

The report is broken down into a number of sections to meet these objectives. The first section reviews the life cycle and habitat needs of salmon to identify the key life stages that can be used to assess the conservation status of stocks and the main environmental factors that may affect status. This information is then used to evaluate the monitoring needs for salmon stocks in rivers and formulate the appropriate strategy. Finally, the mechanisms for establishing conservation limits for sustainability of specific stocks are described.

2. Life cycle and habitat requirements of salmon

The life cycle of the salmon has been described in detail in the literature, reviewed by Hendry & Cragg-Hine (2003). Interrogation of the life cycle indicates the areas where monitoring should be targeted to ensure adequate assessment of the status of salmon stocks in a particular river. The habitat requirements to support the different life stages are complex (see Hendry & Cragg-Hine 2003) and summarised below, to focus attention on the relevant environmental variables for which information should be collected during routine monitoring programmes.



Sarah Wroot

Figure 1. The Atlantic salmon has several life stages (beginning bottom right). The adult female lays eggs, which are fertilized by the male. The spent adults are then known as kelts, and while a few return to sea to spawn the following year, most die. The eggs hatch into alevins, dependent on their yolk sacs; then grow into fry, parr and smolt, when they first migrate to sea. Up to four years later, they return to their natal river to spawn.

2.1 Adults and spawning requirements

Salmon return from the sea to their natal river, and seek to spawn in their natal tributary. Free movement upstream to the spawning sites is therefore a fundamental requirement that must be met. Obstructions come in many forms: Chemical obstruction may be caused by plugs of deoxygenated or polluted water, particularly in estuaries or the lower reaches of rivers. Physical obstruction can be caused by dams, weirs, rapids and waterfalls, and may be natural or man-made features. The ease with which some of these can be passed varies with river flow. Rapids, flow over inclined surfaces and some weirs are negotiated by high speed swimming. The ability of salmonids to pass such obstacles will depend upon water velocity over the obstacle and upon the swimming capabilities of the fish.
There is considerable variation in the temporal patterns of upstream movement of potential spawners.

Factors believed to influence the readiness to move upstream include:

- The physiological readiness of the fish to spawn.
- River flow.
- Water discolouration – movement occurs most readily during darkness or periods of water discolouration.
- Water temperature – movement is inhibited at temperatures above about 18°C and probably ceases entirely between 22°C and 25°C.

River flow is considered an important influence on the willingness of salmon to enter a river and move upstream. There are three conceptual models to describe the influence of flow on upstream movement.

- Adult salmon require certain minimum (threshold) flows to be exceeded before they will move upstream, and these flows are defined as percentages of the average daily flow (ADF). For salmon, 30–50% of ADF is considered necessary in the lower and middle reaches of rivers (50–70% for large spring salmon) and >70% ADF in the headwater streams.
- Salmon tend to move only during certain parts of the hydrograph, usually the rising and falling limbs, or the falling limb only, rather than the spate peak.
- Two annual phases of movement occur with peaks in June to August and October to December.

Salmon exhibits spawning site selection which is governed by a complex of environmental cues, including intra-gravel flow, gravel size, water depth, stream velocity and cover (Crisp 2000). These factors are essential for successful spawning, egg survival and hatching and thus must be monitored.

2.2 Eggs, incubation and inter-gravel stages

The probability of survival of salmon eggs and inter-gravel stages depends on a complex of interacting factors. One of the most important is oxygen supply, which is dependent upon dissolved oxygen concentration and inter-gravel flow. The removal of toxic metabolites, especially ammonia, is also dependent on inter-gravel flow. High egg survival can be expected if dissolved oxygen concentration remains $\geq$6 mg l^{-1} (lower values may be tolerated at low temperatures and if apparent velocity is at or above 0.03 cm s^{-1}).

Gravel composition influences the survival of inter-gravel stages through its effects on inter-gravel flow (hence oxygen supply rate) and also its effects on the ease of movement of alevins at the 'swim-up' stage. The main factors involved in inter-gravel flow are gradients in stream surface profiles, gravel bed permeability, gravel bed depth and bed surface configuration. In general, incubation success decreases as the content of fines (<0.83 mm) in the gravel rises above 10–15%. Thus, high concentrations of suspended solids in the river are undesirable as they are likely to result in infilling of the gravel pores with fine material. Patterns of discharge affect the hydraulics of inter-gravel flow, transport, and deposits of fines; gravel beds may be moved and salmonid eggs and alevins washed out by high flows. This is considered a major cause of egg mortality in salmon. Sensitivity to mechanical shock soon after fertilization, and over-cutting by late spawning fish can also cause mortality.

Water temperature also has a direct effect upon survival of salmon eggs. The lower and upper lethal temperature limits are <1.4 and 15.5°C respectively, and the temperature range for >50% survival to hatch is 1.4–11.0°C.

2.3 Juveniles and smolts

Salmon fry emerge from the gravel by night and take up territories in the surrounding area. Dispersal of salmon parr occurs up to mid-August. The majority (70%) of young fish move less than 100 m although downstream distribution of up to 1 km has been observed. Newly-emerged salmon occupy territories of 0.02 to 0.03 m^2, while larger parr and smolts have territories of >1 m^2. Territory size increases with fish size to 0.2 to 0.5 m^2 at 5 cm length and 5 to 50 m^2 at 10 cm length. Territory size, hence carrying capacity, also depends upon the proportion of river area suitable for occupation by fish of different species and sizes, and on the availability of shelter and food. There is a general movement of salmon to deeper water as they grow. Availability of a natural sequences of riffles and pools, natural sinuosity of the channel, and cover in the form of boulders, undercut banks and coarse woody debris increase carrying capacity.

Water temperature triggers feeding and smolt migration. The optimum range over which feeding and hence maximum growth occurs is 16–17°C.

The EC Freshwater Fish Directive (78/659/EEC) sets a mean value of <25 mg l^{-1} for inert suspended solids in salmonid rivers. Good to moderate salmon fisheries are possible in water with 25–80 mg l^{-1} suspended solids, with the latter level only being exceeded for short periods in natural spates.

3. Existing monitoring methods

The review of the salmon's life cycle and key habitat features highlights the monitoring requirements for condition assessment and the potential mechanisms by which these requirements can be derived. These are summarised in Figure 2, which shows the key life stages where monitoring should be targeted, and the supplementary environmental information and analysis required to undertake condition assessment. The following section examines the methods currently used to monitor the different life stages, their limitations and advantages.

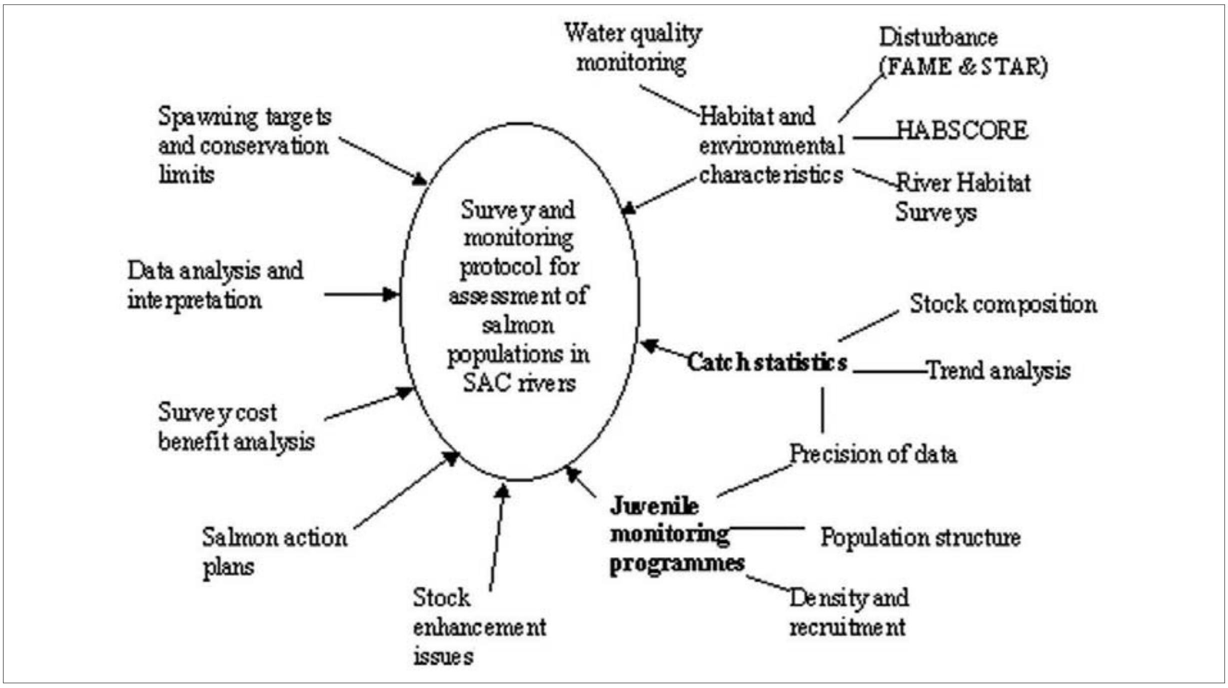


Figure 2. Summary of the monitoring components for condition assessment of Atlantic salmon populations in SAC rivers. Key monitoring activities are shown in bold. (FAME and STAR are EU research programmes targeting the monitoring requirements for fish under the Water Framework Directive).

3.1 Adult run size

The size of a run of migratory fish can be monitored and measured by various means, including rod catches, trapping of upstream migrants and automatic fish counters. Data on run size are essential to estimate spawning escapements, exploitation rates and to investigate the relationships between stock and catch, and between stock and recruitment.

3.1.1 Upstream traps and counters

The size of a run of migratory fish can be monitored and measured by various means, including trapping of upstream migrants and the use of electronic fish counters. Data on run size are important to calculate spawning escapements, exploitation rates and to investigate the relationships between stock and catch, and between stock and recruitment.

Upstream trapping samples the runs of salmon and sea trout entering rivers throughout the year. It is labour-intensive, and the capital costs of structures and installation are high. Care is needed to minimise handling stress in the fish, and unless full-width traps are used, mark-release-recapture techniques are necessary to estimate population size. In addition, there is a likelihood of large on-going costs in terms of structural maintenance. Nevertheless, trap data are the most direct and least biased form of annual run measurements and form the focus of assessment on the index rivers of England and Wales (Tyne, Tamar, Dee and Lune). In addition to numbers and biological data (age, size, sex), they also provide important information on species composition, usually essential on rivers with substantial runs of sea trout, which are indistinguishable from salmon of the same size. There are currently upstream traps on a number of rivers in the UK, including ones on the Eden and Spey, but the latter are only partial river traps. As the Eden and Spey catchments also have electronic counters located in the lower reaches, it is not necessary to run the traps on a routine basis. Operation of these should be limited to special investigations only.

Automatic resistivity and hydroacoustic counters provide direct measures of run size and their use has increased in recent years as a result of improvements in technology and counter accuracy. Existing counters have proved to be of significant value in supplying information on the size and timing of runs of migratory fish; and counters operated with video cameras have provided additional biological information such as species and sex. Full validation of all electronic counters is absolutely necessary, usually by use of video equipment, although other recognised techniques can be used.

The installation of fish counters has previously been notoriously expensive and the operational costs are equally high. However, the VAKI Infra-red fish counter, as installed on the River Ettrick, is suitable for use in fish passes, is relatively inexpensive and has low running costs. Given the international importance of SAC rivers, fish-counter use should be adopted on SAC rivers, and any resources available at a national level to expand the use of counters or traps should primarily be considered for allocation to these rivers. Counters already exist on the Eden and Spey, and although the Eden trap is sited on a tributary (the River Caldew), it will provide an indication of the run size of this particular stock. A resistivity fish counter also exists at Corby Hill on the lower part of the Eden, which provides appropriate data on the migratory salmonid run to the greater part of the river. Hydroacoustic counters are in operation on the Rivers Spey and Wye and provide data on the upstream migration which is validated against video records.

For other SAC rivers, until or unless counters are installed, elucidation of run characteristics can be gained by comparing the information from rod catches on the SAC river with rod and counter data from the nearest monitored river. This is the procedure adopted at present for evaluating the status of salmon stocks in England and Wales. Care must, however, be taken to ensure the run characteristics of the monitored and target river are similar in terms of timing and size composition (grilse versus multi-sea-winter [MSW] salmon). A particular problem with using purely catch data is that salmon can enter the river after the fishing season has closed and will not therefore be reflected in catches.

In the UK, recognition has been given to the need to further expand the use of index rivers (DEFRA 2003). Given the corresponding need and desire to improve monitoring on SAC rivers in relation to the Habitats Directive, there is a strong rationale for considering establishing SAC rivers as index rivers, which necessitates the installation of a fish counter.

3.1.2 Rod and net catch statistics

Rod and net catch statistics are collected from all migratory salmonid rivers in the UK, and considerable historical data exist. Declared catches provide two important categories of information:

- An estimate of the yield from a fishery, which reflects the fishery performance.
- An estimate of run size, based on various assumptions about the relationship between catch, fishing effort and stock.

For most rivers, catches are currently the only indicator of run size. The size of the run can thus be used as a measure of conservation status by comparison of the actual run against a long-term average run size. Rod catch data also provide information on trends in the status of the stocks in terms of fishery performance, which can be correlated against environmental parameters or shifts in stock composition. More importantly, perhaps, is that the timing of the adult run is strongly associated with the fish's targeted location for spawning, with earlier running fish of any given sea age penetrating rivers further before they spawn. This has been demonstated in large catchments, but such relationships have not been examined on smaller catchments including chalk rivers. Recruitment to the fisheries varies independently among temporal components of the catch (Youngson *et al.* unpublished) and by inference, therefore, among the corresponding population groupings. Thus assessment of populations based on catches of adults passing through the fisheries, or counts of adults on passage in rivers, must include an appropriate temporal element to account for these population groupings.

There are, however, potential weaknesses in rod data (Shelton 2002), including inaccurate reporting, the absence of a rigorous means of assessing angling effort and exploitation rate (especially the influence of environmental factors) and the uncertain link between abundance and susceptibility to exploitation (catchability). In addition, the relationship between rod catch and run size becomes highly variable at lower stock levels (when protection is most needed) (Peterman & Steer 1981).

In spite of these difficulties, approximately linear relationships with good explanatory power have been reported between the availability of Atlantic salmon for angling determined from counter data and the reported annual catches for the River Frome in England (Beaumont *et al.* 1991) and the River Bush in Northern Ireland (Crozier & Kennedy 2001). Milner *et al.* (2002) describes such relationships for seven English and Welsh rivers, noting that exploitation rate appears to increase at low stock sizes in chalk rivers. No consistent pattern was seen in spate rivers. However, both the Frome and Bush are small rivers when compared with, for example, Scottish east-coast rivers. Notwithstanding this, rod catch data have been used reasonably successfully to infer abundance at a regional level.

The various agencies are committed to improving the quality of catch statistical data under NASCO obligations and every effort should be made to encourage accurate returns. However, these efforts should be coupled with improving the quality of the data by linking the catches to location in the various rivers, date of capture and the size of fish caught (such as timing of return against duration at sea). This is particularly important because the shifts in stock composition in relation to time of return and location of spawning in the catchment are important criteria for conservation of stock structure, especially with respect to large spring run salmon. To assist this process, where possible, scale samples should be taken from the capture fish to improve and validate the stock composition. Catch and release is now common, and more that 50% of total catch is released in England and Wales. Scales should therefore only be taken from retained fish, rather than those which are to be released, as the increased handling time which this would incur may reduce the survival of released fish. It should be recognised that ageing salmon from scales is not always an easy operation, especially with respect to the juvenile freshwater phase of the life cycle, and ageing results should be validated by a known expert.

Despite recommendations of further use of counters and other fisheries independent stock assessment methodologies, it is recommended that any monitoring programme makes full use of existing rod and net catch data held by the various agencies and attempts are made to promote better information retrieval systems from fishermen and fisheries owners, particularly in relation to the run timing and angling effort.

3.2 Smolt output

Smolt output is a critical fisheries reference point for salmon, because it represents the outcome of freshwater production. However, several operational difficulties present challenges for accurate estimation of smolt production in many cases.

Smolt traps are useful for monitoring the life history and biological characteristics of juvenile populations, and can be used to collate data on numbers, length, weight, age and general condition of the migrants. This data is necessary to monitor changes in freshwater and thus identify and interpret responses to long term (such as climate change) or shorter term (such as environmental quality) variations in the SAC river.

Smolt traps can provide total counts, if they trap the full river's width, or statistical estimates based on mark-recapture if they are only partial traps. Smolt traps are subject to a number of risk areas, including: river spates affecting trap efficiency; significant resource requirements in terms of manpower (for stock assessment purposes, a trap should be in operation 24 hours per day, from March to July in any one year); the possibility that a river features an autumn smolt run; and the risk of post-trapping mortality, which has yet to be fully investigated.

Few trapping facilities currently exist for downstream migrants on UK rivers, but a rotary screw trap on the River Lowther may provide support information for the River Eden. The installation of an infra-red counter as discussed for monitoring adult runs would also enable the monitoring of smolt migration. Traps or infra-red counters located on tributaries would provide a highly valuable catchment scale picture of smolt output.

Despite the technical and resource implications of smolt trap operation, their use should be considered on SAC rivers. Where smolt trapping is adopted on SACs, handling should be avoided by the use of photographic measuring and counting. Microtagging should also be avoided due to the handling entailed (adipose fin clipping and tag insertion), and the need to sacrifice adults to obtain tag data. Passive interrogative transponder (PIT) tags, combined with PIT tag detectors incorporated in fish passes may offer the benefits of microtagging with automated, non-invasive recording of returning PIT tagged adults.

3.3 Spawning activity

One possible measure of spawning activity is redd counting. The number of spawners might be deduced from counts of redds made at local population scales, but Youngson *et al.* (unpublished) suggested that redd numbers do not correlate strongly with adult numbers or with subsequent juvenile production. Taggart *et al.* (2001) stated that many redds are void and most others are composite structures that contain the progeny of several females. Even allowing for these effects, few redds appear to contain the number of eggs predicted on the basis of counts of adult females and estimates of their fecundity (Youngson & McLaren 1998). Redd counting is also very subjective because salmon redds are difficult to distinguish from those of sea trout, and the method can be severely impaired by adverse weather conditions. The method is of limited value in terms of identification of spawning gravels, it is not recognised as a scientific technique, and the amount of effort required makes the inclusion of such an activity impractical in any scientific monitoring programme.

However, the technique may be of some value to show whether the spawning area is contracting or expanding, or when used on recovering rivers to determine the presence or absence of spawning. It is also of value to show where salmon have a preference for spawning and linking this to environmental variables such as river bed gradient, substrate size and flow regime. Furthermore, given that early running (spring) fish spawn earlier than late running fish, timing of redd creation may provide indications as to the spawning success of different stock components. Consequently, although redd counting should not be a core part of SAC condition assessment, depending on local circumstances, it may be deemed of value in providing supporting information on condition assessment, and should be considered where observations are thought to provide meaningful information.

3.4 Juvenile monitoring

Electric fishing is considered the best and most cost-effective sampling method for monitoring juvenile salmonid populations from a catchment-wide perspective. The results of electric fishing surveys provide a measure of the extent to which spawning and nursery habitats are being utilised, provide an assessment of the demographic structure of the populations, identify adverse environmental impacts and, in extreme cases, highlight recruitment failures. Results are particularly valuable when viewed in conjunction with data obtained from other sources – for example, fish counters and rod catches. This methodology can also be used to assess the success of restocking programmes, especially at the fingerling and parr stages of the life cycle. Such monitoring can provide statistically robust estimations of fish population size (quantitative stock assessment) in unit areas of stream, or an indication of relative population levels (semi-quantitative, catchment overview).

Quantitative surveys for stock assessment purposes can be used to obtain accurate and precise spatial and temporal information about fish stocks for management decisions – for example, rehabilitation of river sections or restrictions on fishing effort in various tributaries. The sampling strategy to obtain this information must be designed to meet predetermined precision requirements. The number of sites that must be surveyed can be large, depending on the required precision. In addition, an annual programme must be carried out for several years to account for natural variability in the stock status. The methods of surveying necessary to obtain stock assessment information are also labour intensive, requiring considerable time such that on a large catchments additional resources are likely to be required to allow the spatial resolution required to identify bottlenecks and inform management.

Semi-quantitative techniques, such as timed 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, but at a lower level of precision. Accurate estimation of stock size using this technique requires that a calibration exercise is carried out. There is some loss of accuracy if stop nets are not used, although this is usually insignificant if suitable sections of river with natural barriers are selected for sampling.

For a catchment overview, high precision is not essential, and such a calibrated semi-quantitative technique can provide cost-effective information on whether populations are above a minimum threshold that relates 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 juvenile salmonids is that it is restricted to wadeable streams which means little information will be available for the larger main stem rivers.

It is recommended that a mixture of quantitative and semi-quantitative electric fishing surveys are carried out for condition assessment of juvenile salmonids in SAC rivers.

4. Identifying biologically significant units within the catchment

Broad recognition exists that some catchments, particularly large ones, often comprise salmon with a number of discrete biological units or stocks, often based on sea age (Youngson *et al.* 2003) or utilising a particular part of the catchment e.g. a specific tributary. Before a monitoring programme can be devised, it is essential that any such biological units or stocks are identified in order that these can be monitored and managed as separate entities, where this is appropriate and feasible. This is particularly important given that some salmon SACs have been designated for the diversity of stocks within the catchment. Such stocks should be identified by run-timing as indicated by counter and catch data in various parts of the catchment, ideally collaborated by tagging and by genetic studies of salmon throughout the catchment.

5. Assessing population status

In light of existing monitoring methods, it is recommended that two separate assessment strategies are made, based on the status of the adult run, and on juvenile salmon populations – but their outputs should be integrated to give a wider assessment of the stocks, and subsequently how they can be managed. Condition status of each life stage should be assessed against defined targets.

5.1 Adult salmon condition assessment

The adult run is monitored in most European salmon rivers by the appropriate agency or statutory body, using one or a combination of fish counters and catch data (sometimes coupled with effort data). Two strategies for condition assessment are considered appropriate, and the choice is usually dictated by the geographical location and approaches adopted by the various countries in the UK. Consequently, the concepts should be transferable to other EU member states.

5.1.1 Biological reference points

One of the objectives of salmon conservation and fisheries management is to develop a practical basis for managing individual salmon stocks and the environment in which they live in order to optimise sustainable yield. To achieve this, various stock and fishery reference points are set, including spawning escapement and egg deposition. In this scenario, the adult run is monitored in each salmon river by the appropriate agency or fishery body, using fish counters, catch-effort data or a combination of both methods. The number of adults estimated to be lost through exploitation and natural mortality is subtracted from the total run size to generate the 'spawning escapement' (the number of adults surviving to spawn). This escapement is converted to a total egg production for the river and compared to a river-specific threshold value for egg production termed the conservation limit (CL) that is equivalent to the Minimum Biologically Acceptable Limit (MBAL) as defined by ICES and recommended by NASCO (Potter 2001).

All stock recruitment relationships are domed or asymptotic, and the point of maximum gain in terms of recruitment to the adult life stages (such as smolt output) can always be defined unambiguously, irrespective of the shape of the stock-recruitment curve. CL is defined as the stock level that supports maximum gain (Sg), or sustainable yield and represents an escapement level (and thus exploitation rate) that maximises potential yield under the life-cycle characteristics applying to a stock. Sg is always less than the maximum recruitment potential (Sm).

In England and Wales the CL approach has been used since 1996 to provide a refrence point having relevance to the objectives of the Environment Agency's Salmon Strategy (Milner *et al.* 2000). The conservation limit is currently calculated from an assessment of the capacity of the river network (the whole catchment) to generate smolts from spawning and juvenile-rearing habitat, representing the minimum egg production necessary to maximise yield from the system. In England and Wales, it is calculated locally by the Environment Agency (EA) according to EA guidelines, summing up the total area of usable habitat within the catchment and multiplying by an egg density value that reflects the intrinsic quality of the habitat for smolt production. No such criteria are available for Scotland and Northern Ireland. However, assessment based on adult population structure – spring-run and multi-sea winter (MSW) stock versus one-sea winter (1SW, grilse) fish – may offer a way forward, especially as MSW fish are considered a critical component of the fisheries which is under the greatest threat.

MBAL is also the conservation limit set by NASCO, which suggested it is the threshold below which stocks should not fall, and recommended that to achieve this managers should probably aim to hold escapement at a rather higher (but unspecified) level termed the management target. The current compliance scheme existing in England and Wales operates by specifying that compliance is achieved only if the CL is exceeded in four years out of five. Providing that this is achieved, stock levels over this period will be significantly higher than the CL, effectively creating a more precautionary management target. A procedure for establishing the conservation limit based on rod catch data is described

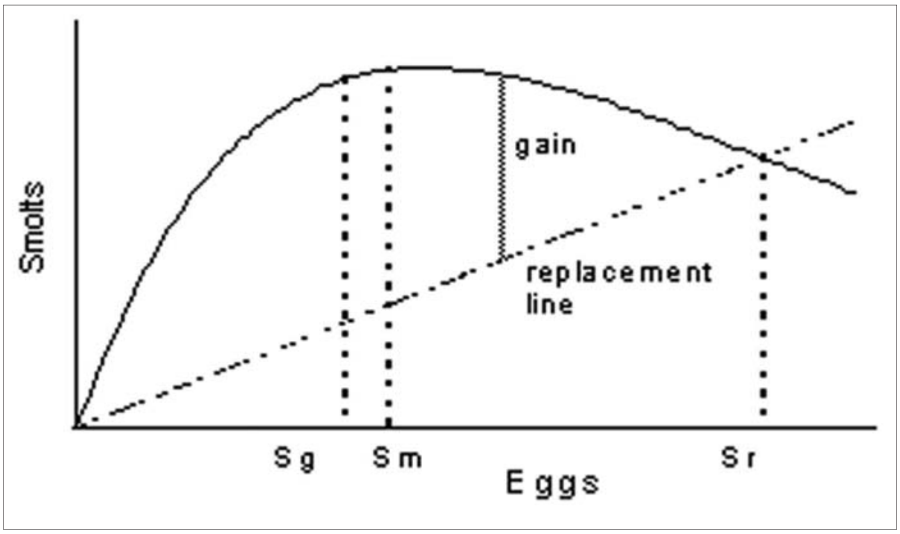


Figure 3. Spawning target options derived from a stock recruitment curve and replacement line. Sg = maximum gain, Sm = maximum smolts and Sr = maximum spawning stock (from Milner *et al*. 2000).

below. This is based on the procedure for establishing conservation limits used by the Environment Agency and NASCO (Milner *et al.* 2000).

An important point to bear in mind is that, for nature conservation purposes, the CL should be based on the capacity of the river network to produce smolts under conditions of high environmental quality, which is not necessarily existing quality (see Anon. 2003). If existing conditions are degraded in certain parts of the catchment, and the CL is based on existing conditions, the CL will be under-estimated and an over-optimistic impression will be gained of the current status of the population. Conversely, if targets are set based on the historical conditions that established the S-R curve, but these are no longer relevant, then the target may be too high or low for present day conditions (Hilborn & Walters 1992). Even if a freshwater or marine habitat is severely degraded it is still possible to set and manage around a MBAL, which simply ensures a greater component of the depleted stock remains unexploited.

In practice, under present circumstances of low marine survival in many stocks (NASCO 1997) and degraded carrying capacity in some rivers, MBAL targets based on former conditions are likely to be conservative unless adjusted by experienced scientists to account for problems encountered by the stocks. It is therefore important to discuss the calculation of the conservation limit for the river in question with the appropriate agency to check that impacted conditions in certain parts of the river network are not 'hard-wired' into the CL. The approach advocated in Anon. (2003) should be adhered to whereby two conservation limits are established, one based on the inherent ability of the catchment to support salmon in the absence of anthropogenic impacts and one reflecting current environmental status. The former, more aspirational conservation limit should be used in determining favourable condition.

Alternatively, it is possible to set the escapement against the expected outputs of smolts based on freshwater mortality from the egg to smolt life history stages. Smolt output reflects the production potential and environmental quality of each catchment so is of great potential value in managing the freshwater phase. Although there are few long-term, direct assessment data on wild smolt outputs in the UK, and the costs of trapping programmes to derive these are high, given the desire to improve the quality and reliability of salmon stock data (DEFRA 2003), SAC rivers provide ideal sites for pioneering improved stock assessment approaches.

5.1.2 Calculating conservation limits in SAC rivers

The first stage in setting the conservation limit is to determine the total area of usable habitat within the catchment or which the biological stock in question uses and multiply it by an egg density value that reflects the intrinsic quality of the habitat for smolt production. In England and Wales this is calculated locally by the Environment Agency according to EA guidelines. No such criteria are available for Scotland and Northern Ireland. Once the area available for egg deposition is known, this must first be back-calculated to the equivalent number of adult female fish that must be allowed to escape to meet this target, and then ultimately related to the declared catch for the river. The total number of eggs to be deposited (E_T) to meet MBAL is given by:

$$E_T = A \times E_D$$

where A is the estimated accessible stream area and E_D the mean egg deposition rate defaulted at 340 eggs 100 m^{-2} (CEFAS/EA 1998). Where a more accurate value for the egg deposition rate is available – for example, the River Eden at 300 eggs 100 m^{-2} – this should be used. The overall total female spawning escapement (SF_T) to meet this egg deposition value is related to the proportion of 1SW (P_g) and MSW (P_m) females (for each sea-age component) in the population (derived from scale or weight data) and their equivalent fecundities (G_f and M_f) such that:

$$SF_T = E_T \;/\; (P_g \times G_f) + (P_g \times M_f)$$

The total number of spawning fish (S_T) is determined from the proportion of females (P_f) in the spawning population as: $S_T = SF_T / P_f$. To calculate the declared rod equivalent to the total female spawning escapement requires an understanding of the relationship between catch (C_t) and escapement.

River annual run = R = C_t / U

Total spawners = S_T = (R – C_t) x s = C_t ([1/U] – 1) x s

where U is the extant rod exploitation rate, expressed as proportion of the total annual run, and s the proportion of fish surviving the in-river phase.

Thus, the catch equivalent to achieving the conservation limit is:

$$C_t = (S / s) / ([\ 1 / U\ ] - 1)$$

This value needs to be adjusted to account for under-reporting of catch as $C_a = C_t / r$, where C_d is the declared annual catch, and r is the rod catch reporting rate. Default values for the parameter estimates are given in Table 1 (Environment Agency 1996), but they can be altered for each river depending on available data.

Table 1. Summary of default values used in spawning escapement (details in Environment Agency 1996).

Parameter	Value	Comments
R, rod catch reporting rate	0.91 for 1994 *et seq*	Adapted from Small (1991), value varies with licence and reminder system.
Pg, proportion of 1SW fish in catch	Approx. range: 0.4 to 0.8	Several alternative methods, analysis of monthly weight frequency preferred.
U, annual extant exploitation rate	Range of mean values for different rivers: 0.09 to 0.42	Variable between years and run groups, default method is based on relationship with fishing intensity.
S, in-river survival to spawning	0.91	Based on radio-tracking studies.
Pf, proportion of females	Pf (1SW) range: 0.3 to 0.6Pf MSW) = 0.69	Pf (1SW) estimated from river size relationship.
f, eggs per female	1SW = 3766 MSW= 7278	Preferred method applies equation of Pope *et al.* (1961) to spawner weight distribution in1 lb weight categories.

Provisional conservation limits have been set for 68 English and Welsh rivers, 63 through statutory Salmon Action Plans and five through non-statutory action plans. Where calculated based on the catchment being under high environmental conditions including all spawning areas that are naturally accessible (not excluding areas upstream of anthropogenic barriers) these limits can be adopted for informing judgements on favourable condition in SAC rivers as a whole, although in the longer term the conservation limits should be derived for catchment sub-stocks. An example of the derivation of the conservation limit for the River Eden is given in Box 1.

Box 1: Setting of conservation limit for the River Eden

Target	Value
Maximum gain (CL etc)	300 egg 100 m^{-2} or 20.61 million eggs
Spawners equivalent to CL spawning stock	7787
Total rod catch equivalent to CL spawning stock	2139
Declared rod catch equivalent to CL spawning stock	1946

Parameters used to calculate above:
Actual wetted area = 6,875,274 m^2
Fecundity (average number of eggs per female) = 6601
Females = 48%
Post-rod fishing mortality = 9%
Rod exploitation = 20%

In the Eden, the annual egg deposition representing the conservation limit is 20.63 million, and that representing the management target (the average egg deposition of a just compliant stock) is 27.29 million (CEFAS/EA 2003). Using the above procedures, catches can be monitored over several years and evaluated against the CL. Variability in the data has three main components: random error, measurement error and trends including the effects of autocorrelation. An analysis of several rivers in England and Wales (Environment Agency 1996) showed that salmon catch data are strongly auto-correlated (lag-one autocorrelation ranging from 0.3 to 0.6), although it is difficult to distinguish this effect from genuine trends due to external factors acting on the stock. Statistical rules were developed to account for autocorrelation and random error effects (Environment Agency 1996), which set a 20 percentile standard for egg deposition (on average, egg deposition should be above the Sg value for four years in five) and accepted Type 1 error occurrence of 5% (there should be a false alarm only once every 20 years). This procedure means that in conditions of a stock being just around the CL, the mean egg deposition is actually somewhat higher than CL (Figure 4).

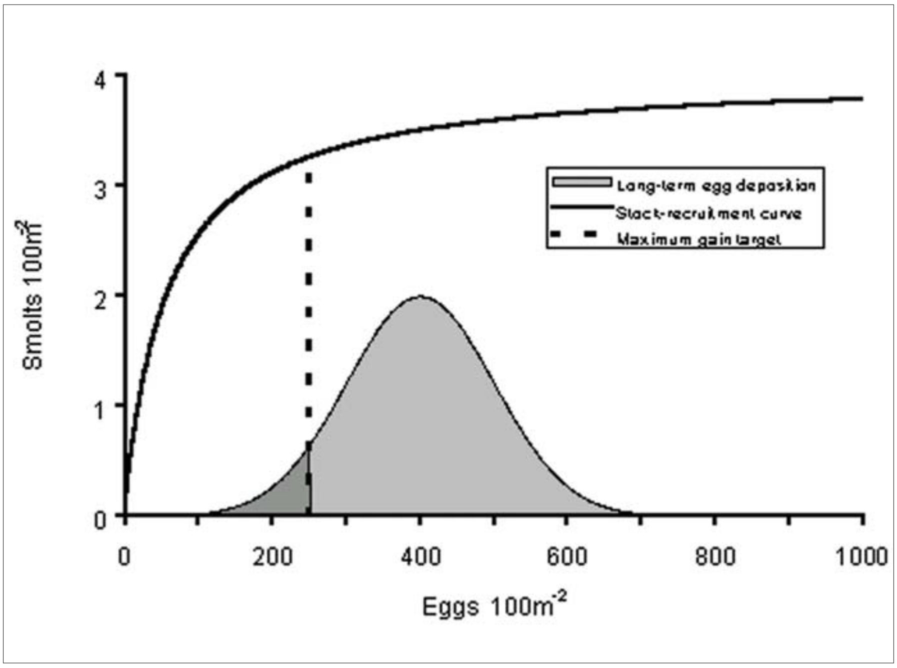


Figure 4. Environment Agency conservation limit compliance scheme showing frequency distribution of escapement (as eggs) for a stock just passing its conservation limit(Sg), in which 20% of annual values fall below the "limit"

Thus for condition assessment, the status of the adult run is based on the observed annual spawning escapement over a three-year rolling period. Compliance is considered acceptable if the run size exceeds the conservation limit for 80% of the time (in four years out of five – see SAP guidelines 1996 for description of the statistical basis). This is the standard Environment Agency assessment, and figures are available from the annual report on salmon and fisheries statistics (Environment Agency/CEFAS 2000). For the purposes of condition assessment, all five years of data should lie within the reporting period. Similar data and reporting procedures are available in Scotland and Northern Ireland.

A problem arises in that the standard assessment of the adult run currently operates at the level of the whole catchment, probably including river reaches from outside the designated SAC site. This is the same issue raised for monitoring juvenile fish where the SAC is often related to the stem river, but it is impractical to derive or separate assessment data for this component of the river basin. The simplest and crudest way to report on SAC site condition is to apply the results of the assessment to each reporting unit that can be discriminated within the SAC, bearing in mind that there is the potential for population status to vary around the site. Integration of data from assessment of juvenile populations will provide better information on variations in status between reporting units, and every effort should be made to integrate these data.

5.1.3 Deriving conservation limits for discrete stocks within the catchment

As outlined in Section 4, any significant biological unit identified should be assessed when reporting on the SAC as a whole. Although conservation limits are currently produced at the whole catchment level, on SAC rivers separate conservation limits should then be derived for each of stocks identified. This approach is in line with the recommendation 35 of the UK government's Salmon and Freshwater Fisheries Review Group Report. Additionally, a more qualitative judgement about any particular stock can be made by comparing its performance with trends of stocks in rivers in the same region, or nationally. This enables river-specific factors to be distinguished from broader trends which may be predominantly due to marine factors.

The need to conserve discrete stock components within a catchment is based on the premise that populations of salmon exploit geographically segregated sectors of freshwater habitat for breeding and juvenile rearing, and for the larger rivers at least, multiple populations exist within single catchments. Exchange of individuals among populations appears to be minimal or absent and, at least in the short term, neighbouring populations do not necessarily compensate for local shortfalls in production elsewhere (Youngson *et al.* 2003).

As a result, any weakness in production by single populations may be directly reflected in the overall abundance of salmon in the fisheries. Furthermore, the timing of the adult return (river entry time) is strongly associated with each fish's targeted location for spawning, and earlier-running fish of any given sea-age penetrate rivers further before they spawn (Laughton & Smith 1992, Webb & Campbell 2000).

Recruitment to the fisheries varies systematically and independently among temporal components of the catch (Youngson *et al.*unpublished) and by inference, therefore, among the corresponding population groupings. The spatial and temporal dimensions imposed by population structuring are therefore critical for assessment, but suitably fine-scale precision in data recording is necessary to allocate returning salmon according to their natal population. In addition to the spatial element associated with populations, the links between run-timing, population membership and spawning site indicate that assessment of populations based on catches of adults passing through the fisheries, or counts of adults on passage in rivers, must include an appropriate temporal element. The effects on population structuring and run timing can thus be used as an assessment tool.

It should be recognised that for complex stocks, such as that found in the River Spey, population structuring and run timing will show high levels of variability and noise which may obscure the expected underlying relationships. This variability can be brought about by factors such as discharge regime linked to precipitation, which influences accessibility of upstream locations for returning salmon, and thus disrupts the run timing and subsequent catches. Consequently, discussions will be needed with local Environment Agency staff to make a decision on whether any changes that have taken place in the composition of the run should be deemed to be unfavourable.

The main problem with this approach is that current resource limitations make it impossible to obtain total coverage for assessments of any refinement on any geographical scale (Youngson *et al.* unpublished). Youngson *et al.* (unpublished) considered that in practice, two compromise approaches are possible. One is to construct generalised large-scale assessments across populations at regional or catchment scales (to aggregate data from a number of rivers in a region). The other is to scale up population level assessments to higher spatial levels (to aggregate data from a number of tributaries of reaches of a river to give a catchment based assessment). Both approaches are potentially valid, but the former is more easily accomplished because historical data have been collected on this scale, especially in Scotland. However, the latter is the more robust, since the validity of generalised assessments is critically dependent on local populations behaving in a similar way.

This approach is not valid if inter-population variation is caused by factors that act on individual populations (population specific). This potential shortcoming of the large-scale, generalised approach is particularly telling if inter-annual trends diverge among populations. It may also fail to identify rivers or sections of rivers that are failing to meet specific conservation limits, with obvious implications for SAC-designated rivers. Nevertheless, this approach has been followed for many years across the UK, as data on commercial and recreational catches in catchments is the usual reporting procedure (Environment Agency/CEFAS 2000). In Scotland there is a tendency to compile catch statistics on a district basis where many small rivers fall within a small area, because assessment of individual rivers is impractical. However, catchment and reach level data exist for the large rivers. Such data go back as far as 1952 so an adequate database for establishing trends is available. A similar long-term data series exists for England and Wales.

Long-term changes in run timing due to fluctuating environmental conditions have occurred in the past, and the current low levels of MSW salmon (largely spring-running) relative to 1SW salmon (generally summer-running) may be part of a long term cyclical pattern dominated either by MSW fish or 1SW fish. Such changes should not therefore in themselves be seen as an indicator of unfavourability.

However, given that such stocks, or groups of stocks as characterised by run time have a genetic basis there is a need to ensure that such stocks are maintained at safe levels. Unfavourable status of any one stock component should therefore be based on an actual stock level (conservation limit) for a particular temporal or spatial stock rather than a shift in stock composition from, for example autumn running fish to summer running fish.

5.1.4 Conservation limits in Scotland and Northern Ireland

In Scotland, the specific approach to be followed has yet to be developed. However, it appears that conservation limits are unlikely to be adopted. Salmon stock conservation in Northern Ireland is currently under review and the development of a system comparable to that in England and Wales, based on spawning targets, is likely (Hendry & Cragg-Hine 2003). In the River Foyle Biological Reference Points, in this case equivalent to maximum recruitment (Elson & Tuomi 1975), have been used for many years, combined with real time run estimation using counters, to manage exploitation.

It is essential to recognise that compliance with just one target cannot provide a comprehensive picture meeting all management information needs. Managers and users must not become so focused on the perspective of one target that other aspects of assessment become excluded or are given much lower prominence in decision-making. The use and non-attainment of spawning targets in any one year must not be seen as a failure to comply, and effective communication between scientists and managers to help understand the process is essential if this tool is to be of value in decision-making.

5.2 Juvenile salmon condition assessment

The appropriate agencies or statutory bodies have extensive routine monitoring programmes for juvenile salmon, providing quantitative and semi-quantitative estimates of salmon fry and parr. A new monitoring programme has been established for England and Wales, which, together with data from rivers trusts is currently the only basis for making a judgement on favourable condition of SAC juvenile salmon populations. In Scotland and Northern Ireland the survey programmes are at present mainly dependent on the fishery boards or trusts. The Scottish Fisheries Coordination Centre acts as the focal point for collating juvenile biomass information in a standardised format, but lack of financial resources within the trusts is a problem that has direct implications on the robustness of the data and implementation of a long term monitoring strategy.

Surveys are generally restricted to wadeable sections of river and thus rarely provide an accurate assessment of main river stem reaches. Consequently, an assessment using this attribute can only be made in reporting units containing wadeable sections. This is a particular problem for many SAC rivers because the designated area is often the channel of the main stem river or larger tributaries, which in many cases are less productive in terms of juvenile densities than the small streams – although, owing to its considerably greater area, the main stem may be the major contributor to a catchment's total salmon production. To overcome this incongruity, it will be either necessary to re-designate the SAC river boundaries to the watershed boundaries, or, from a more practical perspective, accommodate data from these smaller systems into the condition assessment. It is recommended that the latter approach is adopted because it is difficult to discriminate the contribution of components sections/tributaries collected to the overall catchment assessment. It should be noted however, the boundaries of all Scottish SAC rivers are in the process of being redrawn to address this problem. As a consequence, a strategy for comprehensive coverage of the juvenile salmon densities in the various rivers is required, although monitoring juvenile fish in larger rivers may prove impossible. This is described in Section 6.

To make a condition assessment of population status, comparison with reference status is required. Two approaches are generally used. The first approach is to relate the observed juvenile densities to densities that would be expected under conditions of high environmental quality. The intrinsic capacity of rivers to support salmon juveniles varies from river to river and reach to reach such that a uniform target is inappropriate.

Reference densities for any monitoring site on a salmonid river in England and Wales can be generated by the Environment Agency model HABSCORE. The HABSCORE model measures and evaluates salmonid stream habitat features and predicts expected values of juvenile densities (Wyatt *et al.* 1995; Milner *et al.* 1998). Habitat features measured include stream width, depth, flow type, cover, substrate type, gradient, altitude, catchment area, distance from river mouth and chemical conductivity. Based on a series of empirical models, the software predicts estimates of the expected salmonid population and, by comparing these with field survey results, computes the degree of habitat utilisation. Its primary use is in the detection and assessment of environmental impacts by comparing observed and predicted salmonid densities. The methodology can also be used to identify sites where habitat is constraining salmonid populations, which can therefore be targeted for habitat rehabilitation.

The HABSCORE model generates two statistics:

- The Habitat Quality Score (HQS). This is the predicted fish density under reference conditions. Values are given for both salmon fry and salmon parr.
- The Habitat Utilisation Index (HUI). This is the ratio of observed to predicted fish density, indicating the extent to which the habitat potential of the site to support juvenile salmon is realised.

The HABSCORE predictions are useful for compliance testing because the HQS score identifies locations where the population is below the expected level as a result of degraded and/or changing habitat conditions. The HUI score indicates where there is failure in the recruitment process, although further work would be necessary to determine if the failure is due to poor spawning or poor egg to fry/parr survival.

HABSCORE predictions should be available from the EA for all routine salmon monitoring sites in England and Wales, but no such analysis is available for Scotland and Northern Ireland. HABSCORE should be relevant to at least some Scottish rivers, although its predictive power is likely to be poorer because it was developed on rivers in England and Wales, which are rather different in typical habitat features and climatic conditions than many Scottish rivers. It should be noted that the HABSCORE model is less reliable in chalk-stream habitats and large lowland salmonid rivers, but this is reflected in the confidence limits around the HQS values provided by the model.

For the purposes of condition assessment, monitoring sites should be grouped according to specific stock concerned and an assessment made of all HUI scores generated within the reporting period. This can then be related to the most relevant SAC unit. There is considerable uncertainty in HABSCORE predictions and fishery survey data that need to be taken into account in this assessment. As a general rule, if the confidence interval around a HUI score encompasses the value 1 (i.e. observed density = predicted density), the status of salmon at that site cannot be distinguished from reference conditions. For assessing conservation status a stock might be said to be in favourable condition when the confidence intervals of at least 80% of HUI scores generated within the reporting period encompass unity. The precise definition of the proportion of sites falling within this criterion will have to be defined based on experience and quantitative data from testing this protocol.

Despite its limitations, the HABSCORE approach should be adopted for all SAC rivers. The scoring is labour-intensive, but given the greater temporal stability of habitat features compared to fish populations, the return frequency can be less, perhaps as little as every 10 years. Consequently, the greatest effort is needed at the start of any survey programme. Details of the methodology are contained in Wyatt *et al*. (1995).

Given that HABSCORE may be of less value on rivers outside the reference sites on which it was developed, in the longer term consideration should be given to developing HABSCORE or similar models which are more directly applicable to the rivers concerned. There is a particular need to develop better quantitative tools for chalk rivers and rivers in Scotland. Some English rivers may benefit from a modification of HABSCORE.

The second approach classifies the density of juvenile salmon in order to establish the relative condition of fish populations in rivers. In England and Wales, the National Rivers Authority (NRA, the forerunner of the Environment Agency) developed a classification scheme (NRA 1994), based on a juvenile database derived from over 600 survey sites. This scheme enables the comparison and classification or grading of a river system based on juvenile salmon monitoring data. The classification of juvenile salmonid density makes use of 'absolute' bands ranging from good (A) to poor (E) (Table 2).

Table 2. Atlantic salmon abundance (fish per 100 m^2) associated with absolute classifications in the National Fisheries Classification Scheme (NRA 1994a). Grades run from A to F (e.g. grade A >86 and grade B 45-86 0+ salmon per 100 m^2).

Species group	Class					
	A	B	C	D	E	F
0+ Salmon	>86	45–86	23–45	9–23	>0–9	0
>0+ Salmon	>19	10–19	5–10	3–5	>0–3	0

This can be tailored to take into account habitat availability and produce a 'relative' classification based upon all sites of the same broad habitat type. Compliance with a high classification category suggests the population is in good condition whereas low grading highlights rivers/reaches/sites in poor condition although where adopted, defined targets for favourable condition will have to be derived. No comparable system is presently available for Scotland. However, given that electric fishing surveys in the most productive Scottish rivers indicate that the densities of salmon frequently exceed the 'A' class grade in England and Wales, a new absolute classification scheme is being developed for Scottish rivers. The absolute classification approach should only be used as an interim until HABSCORE can be established for each survey site, thus enabling the habitat utilisation model approach to be adopted.

6. Juvenile monitoring strategy

Juvenile monitoring by electric fishing, coupled with information from catch statistics and where appropriate counter data, is proposed as the approach to provide an overview of the status of salmon populations in SAC river catchments. The main objective of the monitoring will be to detect change in the population or populations that can be used to stimulate management action. Consequently, the survey design must be able to detect change with some degree of precision and the field methods must be standardised to ensure the input data are comparable.

In this context, constant effort (timed) electric fishing surveys of fry abundance have been used to provide indices of recruitment to the River Bush, Northern Ireland (Kennedy & Crozier 1993). Parr abundance stratified by habitat characteristics has been used to estimate smolt outputs in French rivers (Bagliniere *et al*. 1993). When combined with the measurement of biological variables, such as age and growth, and habitat measurements (Milner *et al*.1998), juvenile population data provide essential insights into the factors controlling freshwater production and have an important role in salmon condition assessment in SAC rivers.

Furthermore, because adults belonging to a particular biological stock may be recorded at counters or caught outside the geographical area to which they belong, these techniques are of limited value in evaluating the status of a geographically discrete biological stock, with only catch and counter data within that geographical area being relevant to that stock. This emphasises the importance of juvenile sampling in monitoring geographically discrete stocks.

The following section addresses these points for monitoring juvenile salmon in SAC rivers.

6.1 Precision level for stock assessment

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 fish or 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 (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 based on three categories.

Class 1: A population change in time or space by a factor as small as 1.2 (such as 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: A population change in time or space by a factor as small as 1.5 (such as 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: A population change in time or space by a factor as small as 2.0 (such as 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 salmon populations in SAC rivers, precision levels 2 or even 3 are 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.

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 and 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 – see Cowx 1983) at each site. The precision is chosen as one of the classes previously suggested. The number of sites is determined from:

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

where C_{pop} is the spatial variation of population size among sites expressed as the coefficient of variation (standard deviation/mean) and CV_i 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 (see above). It is therefore necessary to have a measure of the size of the target area in relation to the area being sampled by each replicate before one can calculate the minimum sample number for the given precision level. The CV can be determined from a pilot study or from data from similar populations collected during routine monitoring programmes. The following example clarifies the application of the equation.

In a small salmon stream, the target area is divided into S (= 92) sections of equal length (100 m). A random sample of sites (n = 7) was selected as a pilot study. In each of these, a three-catch removal exercise was carried out to estimate the population size at each site. 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. The catch probability (P) using Zippin or Carle and Strub estimates (see Cowx 1983) was 0.68. Therefore CV_i using P = 0.6, number of removals k = 3 and an average populations size N = 127 can be calculated as follows. The sampling variance is determined as:

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

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 $CV(N_i) = 0.024$. Finally, if the precision level of the assessment is set as Class 2, *viz*. CV = 0.10, the number of sites (n) required would be of the order of

$$n = 92\,(0.68^2 + 0.024^2) / ((92 \times 0.10^2) + 0.68^2) = 30.8 = 31.$$

If the level of precision is restricted to Class 3 (CV = 2), the sample size would be about 11, and for Class 1 (CV = 0.05) about 62 sites.

When selecting the sites, it is important they are representative of habitats/biomes within the catchment. To this end it is imperative that sites are chosen on headwater and low reach tributaries, as well as the main river. Stratification of the tributaries according to width and depth would be appropriate, although it should be recognised that accurate assessment of juvenile salmon population abundance in large deep rivers is virtually impossible. When choosing sites, due consideration should also be given to ease of access and safety of operational personnel.

6.2 Selecting sites

Once all significant biological units or stocks have been identified and their individual geographical spawning range determined, it is necessary to devise a monitoring strategy capable of adequately monitoring each of these. The number of quantitative sites selected should be chosen according to the procedure in Section 5.1, whereas semi-quantitative sites should be located at 1.5 km intervals. As electric fishing will be undertaken to provide an overall condition assessment of the salmon stocks within the SAC and ultimately the SAC as a whole, SAC river catchment, sites selected must be able to represent the status of salmon populations. Sites must be utilised for salmon spawning, and must be spaced in such a manner as to provide adequate geographical coverage of each stock, and the catchment as a whole.

6.2.1 Frequency of surveys

A two-phase approach is recommended comprising:

- Annual catchment-wide semi-quantitative (timed) survey conducted at a resolution of one site per 1.5 km.
- A rolling programme of quantitative (multi-depletion) fishing targeted at each biological stock within the catchment. Each stock should be surveyed at an interval of not more than three years.

The first element provides an annual indication of the extent and level of spawning in the catchment as a whole. The second rolling element is intended to provide a detailed picture of each stock, particularly parr life stages. The three-year (maximum) periodicity will not entail the high-resource demands that conducting this level of monitoring annually would necessitate, while still being at a sufficient frequency to fit in with the six-yearly reporting cycle specified under the Habitats Directive.

It is proposed that each spatially segregated stock within the catchment is surveyed in a single year. For example, in the case of a catchment with three spatially segregated stocks the first stock would therefore be entirely surveyed in one year, the second in the following year and the third in the third. Furthermore, it is proposed that each biological stock is surveyed at a frequency of no less than once every three years (a three-yearly rolling programme).

6.3 Sampling procedure

When sampling rivers by electric fishing a standardised fish sampling procedure must be adopted to ensure comparison of data within and between rivers. The European Standards Committee (CEN) has defined a standardised approach to electric fishing surveys in rivers, which provides the framework for the sampling methodology (CEN Directive for Water Analysis. Sampling of Fish with Electricity: Work Item 230116, revision of PrEN 14011, October 25, 2001). It should be noted that this protocol only defines the minimum requirements for sampling in terms of equipment, number of sites to be sampled and the size of site to be sampled. The protocol describes the sampling procedures for assessment of a defined area of river, using appropriate fishing equipment and safety precautions, to provide estimates of:

- Fish abundance.
- Species composition.
- Population structure (age or size).

The procedures are entirely compatible with sampling strategies currently employed throughout the UK but ensures standardisation between regions. Consequently, the sampling protocols designed and used by the EA, SFCC and in Northern Ireland are appropriate and do not need to be adapted for the purposes of establishing condition assessment in SAC rivers. Abundance can be either a relative or an absolute measure of assessment based on a fixed-time fishing of a known area of water. Where practical or appropriate, multiple fishing of the known area should be carried out to assess the efficiency of the sampling effort to obtain absolute estimates of population density. This sampling efficiency can be used for calibration against other sites where timed electric fishing is carried out (Crozier & Kennedy 1994, Cowx 1996). All sampling should be done in daylight hours.

6.3.1 Quantitative sites

A sampling site (also named sampling station in some countries) is defined as a stretch of river representative of the whole river reach in terms of habitat types and diversity, landscape use and intensity of human influence. It should include at least a riffle-run-pool unit, or two meanders. Within a sampling site, one or several sampling (or prospected) areas can be defined. If the river (stream) width is smaller than 15 m, the sampling area usually corresponds to the sampling site. If the river width is equal to or larger than 15 m, several separated sampling areas can be selected and surveyed within a sampling site.

Depending on river width and depth, two different sampling methods can be used. When it is possible (small rivers) each site is sampled by wading. In large rivers, sampling should be undertaken by boat (usually in near-shore areas). In all cases the size of the sample should be sufficient to encompass complete sets of the characteristic river form (such as riffles, runs and pools) to ensure good representativeness of the salmon distribution.

Because of the variability among streams and rivers within and among regions, and in order to ensure accurate characterisation of a salmon population in small streams at a given site, electric fishing should be conducted over river lengths of at least 10 times the river width, with a maximum length of 100 m. However, in large, shallow rivers (width >15 m and water depth <70 cm) where electric fishing by wading can be used, several smaller sampling areas totalling at least 1000 m^2 should be surveyed. These smaller sampling areas should cover all types of mesohabitats present in a given sampling site. Electric fishing for absolute estimates of fish populations in large and deep rivers (depth >0.7 m) is difficult. A stratified sampling procedure is necessary. The length of the sampling site is defined as described above (10 times the river width). The efficiency of electric fishing is probably only considered adequate for the 2.5 m strip adjacent to the bank. The sampling (fished) area is thus calculated by multiplying the 2.5 m section near the shore by the length of the fished zone.

6.3.2 Semi-quantitative sites

Semi-quantitative (timed) sampling sites should be fast shallow riffles between pools and glides including gravel suitable for spawning Crozier & Kennedy (1994). The fishing area will be variable as only the length of fishing time is fixed (5 mins).

6.3.3 Equipment and safety aspects

General equipment and materials (clothing, lifejacket, nets, fish containers, communication equipment, first aid) as well as electric fishing apparatus and safety aspects, should meet the recommendations of the CEN Directive (Work Item 230116), and necessarily in England and Wales comply to the EA standards for electric fishing. Either DC (Direct Current) or PDC (Pulsating Direct Current) can be used but AC (Alternating Current) is harmful to fish and should never be used. All equipment should comply with current CENELEC and IEC standards, and relevant legislation.

6.3.4 Fishing procedures

Fishing procedures and equipment differs depending upon the water depth of the sampling site. The selection of waveform DC or PDC depends on the conductivity of the water and the dimensions of the waterbody. The fishing procedure is described below, separately for wadable and non-wadable rivers. In both cases, fishing equipment must be adapted to sample small individuals (young of the year), to obtain reliable data on age–length structure of the population. Hand nets with mesh size of maximum 6 mm are recommended.

Wadable rivers

Small rivers (brooks) should be electric fished from the bank or by wading. DC or PDC may be used. Operators should fish upstream so that water discoloured by wading does not affect efficiency. They should move slowly, covering the habitat with a sweeping movement of the anodes and attempt to draw fish out of hiding. To aid effective fish capture in fast flowing water any catching net should be held in the wake of the anode. The anode is generally followed by two hand-netters (hard scoops are preferable to nets as fish can be tipped out of scoops into buckets without requiring both hands to be used) and a suitable vessel for transporting fish. Switching the electrode on and off should be appropriate to the waveform being used – for example, with smooth DC it is necessary to recreate the electric field in order to initially stimulate the fish, whereas with pulsed DC the waveform achieves this automatically.

For absolute estimation stop nets should be used to delimit survey zones, followed by a method estimating population densities from repeated sampling using identical fishing effort (for example, Carle & Strub or Zippin methods, see Cowx 1983). For relative estimation it is adequate to use partial barriers such as shallow riffles or weirs. Equipment (power source and control box) is best sited on the bank, with access to the stream section achieved by fitting long cables to the anodes. An alternative is to use backpack-mounted machines. If the stream is of uniform depth then it is possible to float the power source in a small boat to be towed behind the fish catching team.

Non-wadable rivers

In large rivers, the depth (>0.7 m) and variety of habitats make it impossible to survey the entire area. Prospecting from a boat is recommended as wading beyond this depth can be hazardous. Operators holding electrodes and dip nets need to place themselves in positions to optimise use of the electric field. The waveform should be pulsed DC. The boat should either move downstream in such a manner as to facilitate good coverage of the habitat, especially where aquatic macrophyte beds are present or hiding places of any kind are likely to conceal fish, or upstream if the flow is high. In slow-moving water it is not necessary to match boat movement to water flow, and the boat can be controlled by ropes from the bankside if required. In more rapid water it may be important to allow the boat to travel at the same speed as the water flow, only using outboard motors or paddles for manoeuvring, such that the boat remains close to (drifting) immobilised fish. The larger the river, the more difficult and hazardous it becomes to set stop nets. Whereas good efficiency of capture can more or less be achieved with any waveform in small streams, for larger rivers the best practice with regard to manipulation of pulse shape and frequency should be adopted to improve capture rates.

Qualitative, and to a lesser extent, abundance information can be obtained by using conventional electric fishing with hand held electrodes in the river margins and delimited areas of habitat. Alternatively, where resources exist, capture efficiency can be improved by increasing the size of the effective electric field relative to the area being fished by increasing the number of catching electrodes. Arrays comprising many pendant electrodes can be mounted on booms attached to the bows of the fishing boat. The principal array should be entirely anodic with separate provision being made for cathodes. Dependant upon water conductivity, current demands of multiple electrodes can become high, and large generators and powerful control boxes may be needed. Often, however, it is still only possible to sample the margins with any reasonable degree of efficiency, and fish in the deeper water will evade capture.

It should be noted that electric fishing in large, boulder-strewn rivers, typically found in the north of England and Scotland, may be too hazardous and thus condition assessment may not be possible based on juvenile electric fishing monitoring protocols and reliance will have to placed on adult monitoring.

For semi-quantitative sites, the approach outlined in Crozier & Kennedy (1994) should be adopted. This involves fishing in a downstream manner for 5 minutes over shallow riffle habitat. The objective is to record only 0+ salmon (fry). During fishing, salmonids presumed to be 0+ are removed and the number of other presumed 0+ fish seen but not captured is recorded. Where the proportion of captured fish falls below 60% the results should be discarded.

6.3.5 Identifying, measuring and releasing fish

All fish should be identified to species by external morphological characters. Discrimination between juvenile salmon and trout is known to be problematic. In the case of specimens with unclear external characters (hybrids, and closely related species), preserved sub-samples should be brought to the laboratory for further examination.

Measurements of fish length (total length or fork length) should be recorded in mm. In cases of expected significant length overlap between year-classes, structures to identify age could be sampled (scales). Large and medium specimens should be weighed individually. However, length-weight relationships can be used, rather than individual weighing. When the catch is large (more than 200 individuals of a particular species) it may be appropriate to weigh the whole catch of that species, take a sub-sample and count the sub-sample, and thereby calculate the actual number of fish.

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.

Except for the fish needed for further examination, all fish should be released at the capture site following the conclusion of the survey of each site. They should be released into a calm area near the bank, and not in open, fast flowing water.

6.3.6 Environmental monitoring

Environmental information should be collected on each sampling occasion. The primary information needed is listed in Box 2. In addition, a habitat survey should be carried out every 10 years to meet the requirements of the HABSCORE assessment (see Section 5). Standard measurement procedures, such as those outlined in Bain & Stevenson (1999), and developed under the River Habitat Survey (RHS) protocols, should be adopted. A similar habitat assessment protocol has been developed by the SFCC for Scottish rivers. This should be compared with the HABSCORE procedure for compatibility. 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 in Hendry & Cragg-Hine (2003) (www.riverlife.org.uk). HABSCORE and RHS procedures for recoding these data should be adopted.

6.4 Results

A report should be prepared in which the results are presented as abundance, age structure, and area of the sampling site.

- **Species composition** is a list of caught species.
- **Abundance of salmon** should be reported both as total recorded numbers and as numbers per 100 m^2, either from the quantitative equivalent of a timed fishing (determined by calibration) or as an absolute estimate using the appropriate Zippin or Carle & Strub depletion model on successive catches.
- **Size and age structure**: Age can be determined from length-frequency data or scales. Scales should be taken from the shoulder region, when there is a potential overlap of length classes. Age structure should be reported, if possible, as mean length per age group together with standard deviation and number of fish in the sample.
- **Weighing** of individual fish and recording of total catch of salmon.
- **External anomalies**: All fish can be checked for external anomalies and presence of parasites.

Reports of electric-fishing surveys should contain detailed information on the sampling site, sampling procedure and equipment, physiographical data and conditions of sampling, and results of catches. An example of a baseline survey report form is given in Appendix 1. It is recommended that all data are handled on a common database, in a standardised format. The EA National Fish Population Database (NFPD) may prove the best available option for this purpose until a purpose-built system is available. However, the SFCC database should be evaluated to ensure it is compatible with the EA database and information is transferable. Problems may exist with confidentiality of data, so a memorandum of understanding needs to be established between all owners and users of the data.

Box 2. Environmental variables and data to be collected during routine monitoring of salmon in SAC rivers.

Sampling site, staff and objective

Semi-quantitative (timed) or multi-depletion sampling
Sampling site (name)
Type of water (stream, river)
River/stream (name)
Geographic locality co-ordinates (e.g. by GPS or 6-figure National Grid Reference)
Team (fishing staff leader and crew members)
Fishing method (wading upstream, boat, boom boat)
Date (day-month-year)
Time of the day (beginning and end of sampling)

Equipment and prerequisites

Electric fishing equipment (manufacturer and model)
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 (boom/ring, anode diameter, number of anodes)
Use of stop-nets (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) or length of fished shoreline (m)
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)
Photographic documentation (highly recommended)

Catch

Recorded species (common name and reference to scientific name)
Number of specimens
Length of specimens (fork length to nearest mm)
The following details are optional:

- Results from repeated samplings
- Results on weight
- External anomalies and parasites.

6.5 Pre-survey protocols

Prior to undertaking fisheries surveys there is a need to ensure the appropriate access and fishing rights have been granted. Once the sites have been identified permission must be gained from the landowner for access to the river bank, and the fishery owner/occupier for sampling the river. The Environment Agency and various statutory and conservation agencies hold comprehensive lists of landowners and fishery owners/occupiers so full use should be made of these databases.

In addition, in England and Wales, permission has to be sought from the Environment Agency for "consent to use an instrument other than a rod and line to take or catch fish" (to use electric fishing as a method of sampling). The application must be made at least seven days before sampling through the regional fisheries offices of the EA (see www.environment-agency.gov.uk for contact details). Similar clearance will have to be made with the Scottish Executive.

7. Summary of monitoring and assessment process

7.1 Identify biological stocks within the catchment

Before devising a monitoring strategy it is essential to identify any particular biologically significant units (stocks within the catchment) so that these can be monitored as entities in themselves. Specific stocks should be identified on the basis of catchment geography, the association of fish of different sea age or run time with a particular part of the catchment. Genetic information may also be valuable for this purpose. The assessment procedures outlined below should be conducted at the level of the individual stock.

7.2 Assess status of adult life stage of each biological stock

Returning adults are a key life stage to monitor as their abundance will determine the subsequent abundance of juveniles. Ensuring that adequate smolts are produced in order to sustain the population requires that adequate adults return to spawn. Conservation limits on all major rivers in England and Wales are set to ensure that adequate number of adults return to optimise the output of smolts. It is proposed that these limits are adopted as the adult population parameter by which favourable condition will be judged. However, it is proposed that on SAC rivers individual conservation limits are derived and applied to each biologically significant unit or stock that can be identified. To achieve favourable status the conservation limit as measured by counters and/or catches must be exceeded in any of four years over a five-year period in accordance with the Environment Agency's current compliance scheme.

7.3 Survey juveniles of each biological stock

The status of juveniles in fresh water is not only a key component in assessing the condition of a salmon population but is essential in understanding the freshwater environmental factors affecting salmon during this phase of their lifecyle. The population data obtained can be used as the basis for targeting riverine management.

The specific objectives are:

- To obtain a degree of information on extent and level of spawning annually. This should be achieved by a catchment-wide, fine resolution (every 1.5 km) survey, based on semi-quantitative (5-min. timed) electric fishing. This will enable a catchment-wide comparison in a single year, as well as pinpointing areas of poor recruitment where management can be targeted.

- To obtain a periodic (no less than three-yearly), statistically robust assessment of specific geographical stocks

For juvenile condition assessment the optimum utilization model as derived from observed densities of juveniles compared to those expected based on the HABSCORE model can be used. As a rough guide, a reporting unit (SSSI unit or biological stock) might be said to be in favourable condition when the confidence intervals around at least 80% of HUI scores generated within the reporting period encompass unity. HABSCORE data should be obtained for all survey sites, but where HABSCORE data does not exist, as an interim solution condition assessment of juveniles based on this juvenile sampling regime can be made by the National Fisheries Classification Scheme absolute classifications (classes A-E) as currently used by the Environment Agency, or by a similar system such as that being developed for use in Scotland. Decisions will need to be made regarding the grades and frequency of these which correspond to favourability.

7.4 Evaluate the need and potential for monitoring smolt life stage

The number of smolts migrating from a river system is a key parameter for a salmon population, as it represents the total freshwater production of salmon. When taken with adult abundance, mortality and hence any impact in condition occurring at sea can be distinguished from mortality during the freshwater phase.

Consideration should therefore be given to smolt monitoring where existing trapping or counting facilities exist. Where smolt counting or trapping facilities are not present, but it is felt necessary in terms of monitoring the SAC or a particular stock within it, consideration should be given to the installation of such facilities. Consideration should be given to the establishment of SACs as index rivers (which would necessitate the installation of smolt trapping or counting facilities). If the need for further index rivers in the UK is identified, SACs should primarily be considered as candidates for these. Where adopted, approptiate targets for smolt abundance will have to be developed against which judgements of favourable condition can be made.

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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 cover %:	Emergent		Floating		Submerged	
Bankside vegetation:	Left bank		Right bank			
Adjacent land use:	Left bank		Right bank			
Flow regime:						
Species details:						
Comments:						

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*
10 Ecology of the European Otter, *Lutra lutra*
11 Ecology of Watercourses Characterised by *Ranunculion fluitantis* and *Callitricho-Batrachion* Vegetation

Monitoring Series

1 A Monitoring Protocol for the White-clawed Crayfish, *Austropotamobius pallipes*
2 A Monitoring Protocol for the Freshwater Pearl Mussel, *Margaritifera margaritifera*
3 A Monitoring Protocol for the Allis and Twaite Shad, *Alosa alosa* and *A. fallax*
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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.

Numbers of Atlantic salmon are in decline in many of its former strongholds, and in several European rivers this charismatic fish has now become extinct because of impacts such as pollution, migration barriers, commercial fishing or siltation of spawning grounds.

A complex life-cycle, which utilises rivers for reproductive and nursery phases and migration to sea for adult development, poses unique challenges for the monitoring and conservation management of this protected species.

This report suggests monitoring and assessment methods that can be used to determine whether salmon populations are in favourable condition and to indicate what conservation action might be 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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Life in UK Rivers

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