Monitoring Allis and Twaite Shad

Alosa alosa and *Alosa fallax*

Conserving Natura 2000 Rivers
Monitoring Series No. 3

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Conserving Natura 2000 Rivers

This protocol for monitoring allis and twaite shad (*Alosa alosa* and *Alosa fallax*) 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.

Contents

1 Introduction

There is a requirement to monitor species protected under the Habitats Directive, in order to establish the status of the species against a predetermined set of conservation objectives; a process known in the UK as condition assessment. This is carried out at individual sites and can contribute to an assessment of conservation status of each species across its geographical range in the UK.

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

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

Condition assessment must be able to provide information on the present status of the species and give at least a broad indication of trends in population size and structure. The sampling methodology should reflect this. Habitat information is also needed to provide a broad overview of the present and future health of the population.

Data collected must be suitable for comparison between sites and years, particularly if it is to contribute to determining conservation status. The ability to compare different sites is important because sampling protocols and strategies may be used in SAC rivers with different habitat characteristics.

Given resource constraints, this protocol seeks to develop a programme that can monitor compliance with conservation objectives in a realistic and cost-effective way. Wherever possible, the monitoring identified for SAC river species has been integrated into existing programmes, to minimise additional resource requirements and take full advantage of available field survey effort.

2 Overall objectives

The primary aim of this report is to present a routine monitoring programme detailing survey and reporting methods for condition assessment of allis and twaite shad in SAC rivers. Since there are no known breeding populations of allis shad in SAC rivers of the UK, the programme will be used to monitor the condition of twaite shad populations only.

The assessment of condition at individual sites will contribute to determining the conservation status of twaite (and allis) shad across their range in the UK. A separate document contains recommendations for reviewing shad records in rivers across their range in the UK that are not currently known to contain a viable population (Hillman unpub.). In addition to this report, which basically provides a suggested monitoring protocol for condition assessment of shad populations in SAC rivers, guidelines for collecting information that will contribute to assessments of shad conservation status across their range in the UK are provided.

3 Existing monitoring

Monitoring protocols and sampling strategies that are specific to shad are required because current UK Environment Agency fish monitoring programmes are designed to target either juvenile salmonids or coarse fish, and are generally unsuitable for detecting and monitoring shad. Previous approaches to shad monitoring in the UK were limited to juvenile abundance surveys, data on adult shad caught by Severn estuary netsmen and fish entrainment studies carried out at estuary power stations. Currently, records of shad catches in UK rivers are not collated and stored in a systematic way.

To date, the distribution and relative abundance of shad in UK SAC rivers has been assessed using sporadic catch records from anglers and estuary netsmen. This has provided qualitative information, indicating the presence/absence of each species, and to a limited extent their relative abundance, although the latter was not based on any statistically acceptable protocol. Other shad records have come from fish counters, power stations, fish traps and egg surveys in the estuary and river. Egg surveys in the Wye, Usk and Tywi have helped to determine the spawning distribution of shad within these rivers.

Different monitoring protocols and strategies have been recommended for different life stages (Hillman 2002). Routine monitoring of allis (and to a lesser extent twaite) shad has been undertaken in French rivers for over 20 years. Various methods have been tested and developed in France, Portugal and the USA, providing a range of alternative sampling strategies for consideration. The rivers in these countries that contain a shad population are larger than UK rivers, and methods were considered unsuitable for incorporation into a UK monitoring programme. Information on the methods considered and the rationale behind the recommendations given here are discussed by Hillman (2002).

4 Distribution of shad in UK SAC rivers

There are breeding populations of twaite shad in three SAC rivers in the UK – the Usk, Wye and Tywi and Severn. These SAC rivers are also designated for allis shad but are thought to be too small for effective monitoring.

5 Sampling protocol

This sampling protocol was developed following detailed consideration of previous monitoring methods in the UK, and approaches to monitoring shad populations in other European countries and in the USA.

It is recommended that the following data are collected:

- Juvenile density (represented by catch per unit effort, CPUE). Micromesh seine netting is the most appropriate sampling method to assess juvenile shad CPUE in the lower river/upper estuaries, to compare against a set target for each river.
- Adult run size. Fish counters should be used to monitor the time and approximate size of the adult spawning migration, but the exact size of the adult spawning population cannot be derived using existing equipment.
- Spawning distribution within each river. Egg surveys should be used to monitor the extent and prevalence of spawning within SAC rivers.

5.1 Recording adult shad abundance at fish counters

The hydroacoustic fish counters at Redbrook on the River Wye and at Nantgaredig on the Afon Tywi, should be used to count shoals of adult shad as they migrate upstream. After the first six-year monitoring period, population targets can be set based upon the six-year average for total shoal counts. If more than six years' data are available, these too should contribute when calculating a long-term average. Condition assessments should be made by comparing annual shoal counts against a set target derived from the long-term average number of shoals. Details recorded should include the time, date and relative size of shoals, in terms of the amount of acoustic energy reflected by a shoal and detected by the fish counter.

The adult spawning migration in the River Wye is from April until June, with peak migration typically occurring in May (Aprahamian *et al*. 2002). To check that the shoals are shad and not sea trout, video footage should be collected during this period and a percentage (10% of all shoals recorded from April-July) should be viewed to confirm that the shoals are shad. The forked tail and deep body of shad can be used to differentiate between shad and sea trout on video footage.

The timing of recording twaite shad shoals needs to remain flexible each year, because the onset of adult migration will be delayed by high flows or low water temperatures. Indeed, if adverse weather conditions persist throughout the adult spawning run, it is possible that spawning success will be very low and few juveniles are subsequently captured (see case study, Section 9).

Depending on the results of future research into using hydroacoustic fish counters to detect and monitor adult shad, it may be possible to produce a more accurate estimate of adult stock size (Hillman 2002).

5.2 Egg surveys at spawning sites

The extent of spawning in each of the three designated SAC rivers should be monitored each year by kick sampling for eggs at a proportion of known spawning sites. The spawning distribution should be determined from a comprehensive baseline survey in the first year, against which subsequent annual survey results should be compared (Hillman 2002). A reduction in the spawning distribution of more than 50% compared with the initial survey will indicate an adverse change.

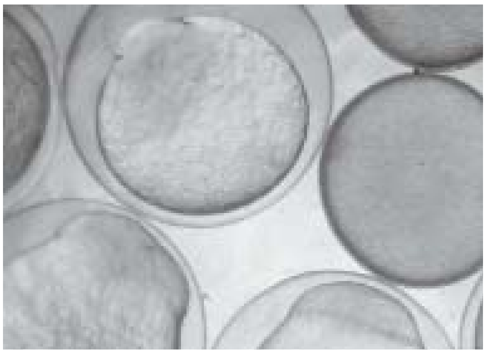
5.2.1 Kick-sampling methods

Kick-sampling should be undertaken over an area judged to be potential spawning habitat. A standard macroinvertebrate hand net (250 µm) should be used to collect material dislodged by kicking upstream of the net for 15 seconds. The net should be checked after each kicking interval and any detritus or channel substrate removed before kicking is resumed. Sampling should start at the downstream end of the potential spawning site to prevent the re-recording of eggs dislodged in previous kicks. If no eggs are found, the survey should be terminated (a comprehensive assessment is judged to comprise approximately 25 kicks, or 30 minutes). If eggs are present, the extent of the spawning area should be determined by progressively kick sampling (about 10 m) upstream and downstream (Caswell & Aprahamian 2001). To confirm the limit of a spawning area, sampling should be continued for at least another five intervals after the last egg is recorded.

Kick-sampling should only take place when river and weather conditions permit. The timing of sampling will depend upon the prevailing environmental conditions each year. Sampling should commence when the first adult shad are observed migrating upstream at the Redbrook Fish Counter. Spawning sites, and the recommended sampling location at each site, should be identified during the baseline survey. Sites should be surveyed in a way that minimises travel costs.

5.2.2 Egg identification

The identification of shad eggs is crucial to this method of monitoring. Eggs are clear, non-adhesive, semi-buoyant and between 1.5 and 5.0 mm in diameter (typically 2.5 mm). The best way to identify shad eggs is by first-hand observation in one of the UK rivers with a population of twaite shad (Rivers Wye, Usk, Tywi and Severn). It is not possible to distinguish between the eggs of allis and twaite shad. If shad eggs are identified, the likely shad species to have spawned should be inferred from the species



Alan Henshaw/Environment Agency

Shad eggs are clear, semi-buoyant and non-adhesive. It is not possible to distinguish between the eggs of allis and twaite shad.

recorded in the catchment; in the Usk, Wye and Tywi this will almost certainly be twaite shad.

5.2.3 Selection of survey sites

Following a comprehensive survey of each of the rivers Tywi, Usk and Wye, (including historical spawning sites where possible) a proportion of spawning sites should be surveyed each year. Historical spawning sites are listed in Aprahamian *et al*. (1998). If 10 or fewer sites are located on each river in the comprehensive survey, all sites should be surveyed in subsequent years. If more than 10 spawning sites are recorded on a river during the initial survey, 50% of sites should be randomly selected for annual survey, provided this equates to 10 or more survey sites. In the Wye, where the historical spawning distribution is extensive, the random selection of sites should be divided between the lower, middle and upper sections of the river to avoid grouping of survey sites in one part of the river.

The number and proportion of active spawning sites each year should be compared against the baseline survey to ensure that the number of spawning sites has not reduced by more than 50%. It is also important to determine the downstream and upstream limits of spawning in each river; on the River Tywi spawning sites have been reported below the location of the proposed fish counter at Nantgaredig. The limits of egg distribution in each river should be reviewed every six years.

5.3 Netting juvenile shad

The principal method for quantitative assessment of shad stocks is micromesh seine netting of juvenile shad in the upper estuary or lower river. Netting should be carried out in late summer early autumn (July-October) in the lower river/upper estuaries of the rivers Wye, Usk and Tywi. The following standard sampling procedure was developed during field trails on the River Tywi (see Section 10). Annual comparisons of catch per unit effort (CPUE) data against population targets will be used to make condition assessments. Targets for the rivers Wye, Usk and Tywi will be set after the first six-year monitoring period.

5.3.1 Sampling strategy

Sampling should be carried out in a systematic manner over the migration period so that sampling effort is equally spaced throughout the period with a frequency dependent on the level of precision required. Sampling should be carried out monthly from July to October inclusive, with more effort focused on the upper estuaries than lower rivers in the later months.

- Seine netting should be undertaken by (at least) three people.
- The timing of surveys each year should be the same, albeit allowing for adjustment of dates to utilise the appropriate tides.
- A minimum of three sites should be surveyed within the lower river/upper estuary of the SAC river (see figures 1–3).
- Three sweeps of the net should be taken at each site.
- Netting should be carried out on the ebb flow of neap tides, on a similar-sized tide each month.
- Netting should be carried out from the river bank or estuary foreshore, using a small inflatable boat to set the net.
- Water and air temperature should be measured during each survey, whilst flow data can be

obtained from Environment Agency gauging stations.

- If weather or flow conditions are unfavourable, netting should be abandoned in the interest of safety.

5.3.2 Equipment

- A 6-mm hexagonal stretched mesh seine net, 30 m in length and 2.8 m in depth, with barrel leads approximately 37 cm apart and floats 32 cm apart.
- A small inflatable boat is suitable for setting the net; the boat should be rowed when setting the net, with the net being set from the back of the boat.
- Containers of ethanol in which to preserve samples of juvenile shad.
- Thermometer.

5.3.3 Location

- At least six potential survey sites should be identified in the lower river/upper estuary, from which three should be chosen based on the results of a preliminary survey.
- Potential sites should be located either in the lower river or upper estuary, see figures 1–3.
- Surveys undertaken later in the year should concentrate on the upper estuary as juvenile shad will have probably dispersed downstream by this time.
- Within the estuary/river, sampling should take place at the edge of the main channel, rather than the peripheral areas.
- In the late summer period priority should be given to sites that yield relatively large numbers of juvenile shad, furthest upstream, where river flow is not as great.

In figures 1–3, the arrow indicates the zone of potential sampling sites.

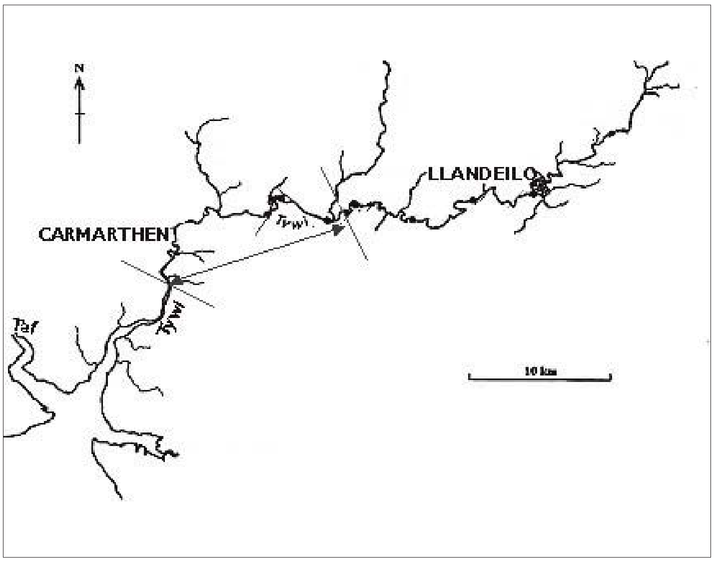


Figure 1. Potential locations for juvenile shad netting on the Afon Tywi.

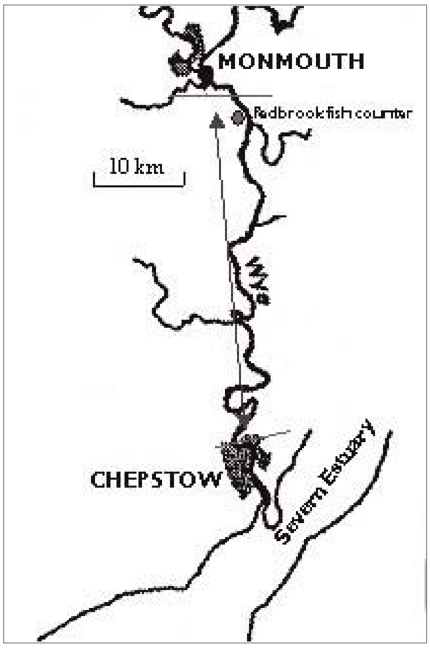


Figure 2. Potential locations for juvenile shad netting on the Wye.

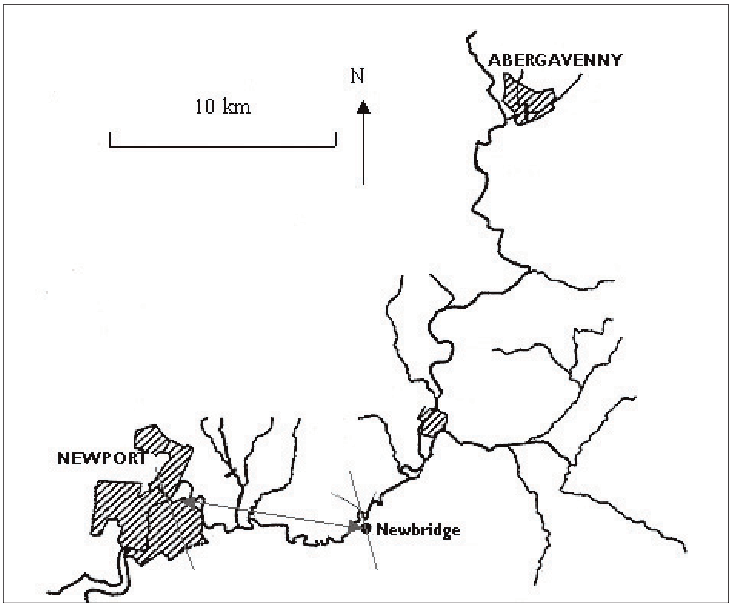


Figure 3. Potential locations for juvenile shad netting on the Usk.

5.3.4 Storage of samples and recording of biological information

Since shad are susceptible to handling, every care must be taken when recording biological information, such as body length. It is recommended a minimum of 30 individuals are measured (fork length, nearest mm) in the field for length frequency analysis. As it is impossible to distinguish juvenile twaite from allis shad in the field, a sample of juveniles should be retained and preserved in 90% ethanol for later laboratory analysis.

A sample of 10 juvenile shad should be retained from one site per SAC river (or the upper estuary) per month. If sampling is undertaken from July to October inclusive, not more than 40 juvenile shad per year should be retained from each SAC river. Considering natural mortality, this figure is unlikely to have a significant impact upon the population. Care must be taken to select a representative sample (when searching through the catch larger fish may be more conspicuous). Preference should be given to retaining juvenile shad that are damaged during the netting and as such, are unlikely to survive. When selecting the sample of fish to retain, care must be taken not to compose the sample entirely of juvenile shad that become 'gilled' in the seine net, because the likelihood of becoming caught in this way is size-dependent. A count of the number of gill rakers of each individual in the preserved samples should be carried out to check for the presence of allis shad, and its contribution to shad populations (Table 1) (Taverny 1991).

Table 1. Relationship between total body length (Lt) in millimetres and number of gill rakers on the first gill arch of juvenile *A. alosa* and *A. fallax* (Br). Based on data from Veron (1999) and Douchement (1981) [*A. alosa*] and Claridge & Gardner (1978) and Douchement (1981) [*A. fallax*].

Lt	Br *A. alosa*	Br *A. fallax*
30	52.2	30.2
40	54.1	30.9
50	55.9	31.5
60	57.7	32.2
70	59.6	32.8
80	61.4	33.4
90	63.3	34.1
100	65.1	34.7
110	67.0	35.4
120	68.8	36.0
130	70.7	36.7
140	72.5	37.3
150	74.3	38.0
160	76.2	38.6
170	78.0	39.2

During the preliminary survey, measurements should be taken from fresh samples and re-measured after a one-week immersion in 90% ethanol. This will provide a conversion factor for length measurements between fresh and preserved samples, enabling juvenile shad to be preserved *in situ* and measured later.

5.3.5 Sample size (statistical confidence in the data)

In order to estimate the total number of juvenile shad to a sufficient level of statistical confidence, it is necessary to undertake a preliminary survey to calculate the variance in the number of juveniles caught between samples, survey sites and months. A preliminary netting survey will also permit the identification of suitable survey sites, based on the following criteria:

- The site must be safe and easy to survey.
- The site should be fairly easily accessible.
- The site should permit consistent sampling (no river reshaping work, dredging, etc.).

- The survey site consistently yields juvenile shad.
- The variance in numbers of shad caught per net is low, compared with the catch variance at other sites tested.
- Non-compliance with the above criteria should result in the selection of another site.

Note: Recruitment in twaite shad is extremely variable between years, but it is not known whether this is due to a variation in the size of the adult population between years, environmental conditions or a combination of the two. The prevailing conditions in the estuary/river during the preliminary survey year should be taken into consideration when deciding if the site is suitable, in terms of the catch variance. The relative effects of stock size and environmental conditions on juvenile recruitment needs investigation.

Statistical precision

The equations for determining the estimates and associated variance, standard deviation, standard error and confidence limits for unequal-size sampling units, sampled without replacement are given by Caughley & Sinclair (1994). The precision of the estimate is dependent on the number of samples taken and should be defined at the outset together with the level of confidence (Aprahamian *et al*. 1998). For example, the programme might aim to estimate the total catch of shad so that the estimate must be within ± 50% of the true estimate, with a confidence of 95% – there is a 1 in 20 chance that the estimate will be outside this range.

An estimate of the number of sampling units (n) can be determined using the following formula:

$$n \geq Var\ (D) / ([d/\ (t_{\alpha/2}])^2 + Var\ (D)/A)$$

where Var (D) is the variance of catch estimate, d the width of the confidence interval, $t_{\alpha/2}$ the upper $100(1-{}_{\alpha/2})$ value of students' t for the $100(1-_{\alpha})$ % level of confidence.

Aprahamian *et al*. (1998) used catch estimates and associated variance of catch, from Oldbury Nuclear Power Station in the Severn Estuary, to calculate the necessary number of samples (days) required to meet various levels of precision and confidence. Below is an example of how to calculate the number of sample days needed, using data from Claridge & Gardner (1978).

Note: For condition assessment in SAC rivers the catch estimate and associated variance should be calculated using data from a preliminary netting survey in the river/estuary of the appropriate SAC river.

5.3.6 Sample size to estimate a proportion

Juvenile shad may spend either one or two years in the estuary of the river where they were spawned. Also, the timing of the seaward migration varies from year to year. As a result of these two factors, it is necessary to estimate the proportion of a particular age group in the population to a given level of precision with C % confidence. The number of fish required for ageing can be calculated using the following formula (Aprahamian *et al*. 1998):

$$N = u^2\ 0.5(1-0.5)/\delta^2$$

where: N is the number of fish to be aged, u the standard normal deviate corresponding to a cumulative probability of (100-C) /2, and δ the desired precision.

The sample sizes needed to estimate a proportion at various levels of precision are presented, for three levels of confidence in Table 2. For example, a sample size of 166 fish is required to ensure the estimated proportion will be within ±0.10 of the true estimate with 99% confidence.

Aprahamian *et al*. (1998) suggested that as males mature approximately one year earlier than females, the age structure of the population should be determined separately for each gender. However, the

Example 1: Calculating the number of samples (days)

Samples were obtained at weekly intervals, between July and November 1975 and 1976. In 1975 the mean catch (D) of shad during the main migration period, August to October inclusive (92 days in total) was 91.58 day^{-1}, and the variance [Var (D)] was 7480.23 fish. The required level of precision is ± 0.50 of the mean catch and the required level of confidence is 90%.

$n \geq Var\ (D)\ /\ ([d/\ (t_{\alpha/2}])^2 + Var\ (D)/A)$

$n \geq 7480.23\ /\ ([45.79/\ 1.645]^2 + 7480.23/92)$

$n \geq 7480.23\ /\ (774.84 + 81.31) \geq 8.74$

The minimum number of samples (days) required is 9 days.

Between-year differences

In order to assess the condition of shad populations in SAC rivers it is necessary to determine whether there has been a significant change in the population between years. The number of samples required to assess whether there has been a significant change in the catch should take into account the smallest difference that the sampling programme is designed to detect, and the probability of making Type I and Type II errors (Aprahamian *et al.* 1998).

To ensure a low probability of committing a Type I error (i.e. falsely rejecting the Null Hypothesis (H0: D1 = D2)) a low α is required (e.g. setting $\alpha = 0.05$ means there is a 5% chance of rejecting H0 (the sample means are not equal) when in fact they were equal). A Type II error is committed when H0 is accepted when the alternative hypothesis (H_α) is, in fact, true. This probability is donated by the value β (e.g. setting $\beta = 0.10$ means there is a 10% chance of accepting H0 (the sample means are equal) when in fact they were different and the probability of accepting H_α when H_α is true is therefore $1 - \beta$ (0.90) and termed power (Aprahamian *et al.* 1998).

The two types of error are inversely related. A decrease in a Type I error will increase the probability of a Type II error, for any given sample size. The only way of reducing both sets of error is by increasing sample size. The ideal statistical test is one which has a small probability of rejecting H0 when it is true and a large probability of rejecting H0 when it is false. The number of sampling units (n) which should be sampled to detect a specific difference in, for example, mean catch (D) at a particular level of confidence and power, can be determined using the following equation:

$n = (2Var(D)/\delta^2)(t_{\alpha/2} + t\beta)^2$

(adapted from Wyatt & Lacy 1994, in Aprahamian *et al.* 1998), where: Var (D) is the variance of the estimate of mean catch, δ the minimum detectable difference between means, $t_{\alpha/2}$ the upper $100(1-{}_{\alpha}/_2)$ value of students' t for the $100(1-_{\alpha})$ % level of confidence, $t\beta$ the upper $100(1-\beta)$ value of students' t for the $100(1\text{-}\beta)$ % level of power.

Table 1. Values of 'students' t for confidence (a) and power (b) for different levels of probability.

Level of Confidence (%)	Probability (a)	Confidence ($t_{\alpha/2}$)	Power (1-β)
99	0.01	2.576	0.99 (1.960)
95	0.05	1.960	0.95 (1.645)
90	0.10	1.645	0.90 (1.282)
80	0.20	1.282	0.80 (1.036)
70	0.30	1.036	0.70 (0.842)

Example 2

Using the data in Example 1 (mean catch 91.58 per day, catch variance 7480.23 fish); if the sampling programme was being designed to detect a minimum difference of half of the catch (δ = 45.79), at 90% confidence (α) and power ($1-\beta$) also 90%, then the mean number of days which would require sampling, would be calculated as follows;

$$n = (2\mathrm{Var}(D)/\delta^2)(t_{\alpha/2} + t\beta)^2$$

$$n = (2 \times 7480.23)/45.79^2)(1.645 + 1.282)^2$$

$$n = (14960.46/2096.72)(8.57) = 61.15$$

The minimum number of samples (days) required to detect a change in mean catch size between years is 62 days.

Aprahamian *et al*. (1998) observed a significant autocorrelation between catch in years n and n + 1. Tests for significant differences between catches should therefore be carried out between catches in the current year and the average catch of the three previous years.

Table 2. Sample size required to meet various levels of precision and confidence. u = Confidence. Values calculated assuming a proportion (p) of 0.5 (i.e. sex ratio = 1:1).

Precision	**Confidence level**		
	90 % (u = 1.645)	**95 % (u = 1.960)**	**99 % (u = 2.576)**
0.01	6765	9604	16590
0.05	271	384	664
0.10	67	96	166
0.20	17	24	42

routine monitoring programme will be sampling the 0+ and 1+ age groups, and it is neither necessary nor feasible to obtain population estimates for separate genders.

5.3.7 Sample analysis

Age data

Interpretation of changes in catch is difficult without additional age structure data or an idea of the relative abundance of year-classes before they enter the adult population. This is because changes in catch may reflect the combined effect of a number of relatively poor or good year-classes passing through the population. Such a situation could arise for example if there were a number of cool, wet summers, as in the late 1980s (1985–1988 inclusive), producing a succession of poor year-classes and a decline in the population as a result of purely natural factors (Aprahamian *et al*. 1998).

Total body length should be measured in centimetres. Using data from other studies, juvenile allis and twaite shad can be assigned to the correct age class (either 0+ or 1+). Aprahamian *et al*. (1998) calculated that twaite shad in the Severn estuary measured 85.4 mm at Year 1 (standard deviation 14.8 mm) and 182.4 mm (standard deviation 35.5 mm) at Year 2. It should be possible to record the age-frequency of 0+ and 1+ twaite shad *in situ*. The mean length per survey month can be calculated and compared to corresponding months between years, to provide an indication of the timing of spawning and the growth rate of juvenile shad.

5.4 Identification of juvenile allis and twaite shad

Identification of juvenile samples should be carried out, as in the case of adults, by counting the number of gill rakers on the first gill arch. A microscope (x10 magnification, for example) should be used to count gill rakers.

The number of gill rakers on the first gill arch of juvenile anadromous shad (*Br*) is positively correlated to total length (*Lt* in centimetres) according to the relationship $Br = a.Lt + b$, thus the typical numbers of gill rakers can calculated for various body lengths of juvenile allis and twaite shad (Table A.2, Appendix A). Veron's (1999) coefficient from the River Aulne, in northwest France, can be used to calculate the gill raker-body length relationship in allis shad ($Br = 1.58.Lt + 45.6$) (Taverny 1991). The same relationship for twaite shad was derived by Claridge & Gardner (1978) from the River Severn population, where $Br = 0.9.Lt + 20.7$.

6 Summary of routine monitoring programme

6.1 Initial baseline survey

6.1.1 Egg surveys

- Undertake comprehensive surveys on SAC rivers with breeding shad populations (Wye, Usk and Tywi) to map all spawning sites as a baseline.
- In addition to baseline surveys at all historical spawning sites, River Habitat Survey techniques should be used to identify new potential spawning sites for surveying.

6.1.2 Juvenile netting surveys

- In SAC rivers with shad populations (Wye, Usk and Tywi) select six potential netting sites (see figures 1–3).
- A minimum number of seine net hauls should be taken at each site, every month from July to October inclusive (three days sampling per month).
- Based on the mean catch at each site, the variance, catch consistency between months and ease of access, three of the six sites should be selected for use in a routine monitoring programme.
- Using data from the selected three sites, calculate the mean catch density and the variance per site, on each river.
- Using the calculated density and variance per river, calculate the required sample size (nets, tides, hours or days) at different levels of confidence and precision.
- Select the maximum level of confidence and precision that can be afforded, in terms of monitoring costs.

6.2 Routine monitoring

6.2.1 Fish counters

- Count shoals of migrating adult shad and record deflected energy.
- Record date and time of shad migration.
- After first six-year monitoring period when target shoal counts have been set, compare number of shoals with the target.

6.2.2 Egg surveys

- Randomly select 50% or 10 (whichever is greatest) of the known spawning sites per designated SAC river and search for eggs by kick-sampling.

- The absence of eggs from more than 50% of sites surveyed will denote an adverse change in the spawning distribution in the river .

6.2.3 Juvenile netting surveys

- On at least one day per month (depending upon the number of samples needed to permit statistical confidence in the data set, calculated in the preliminary study), from July to October inclusive, undertake three nettings, at each of three sites, per SAC river (or the associated estuary). Where possible, measure 30 juvenile shad in the field for length-frequency analysis.
- Calculate density and catch variance per river using data collected annually.
- Retain samples for measurement of body length and calculate the proportion of 0+ and 1+ group fish in the population.
- Examine the gill rakers to assess the proportion of twaite and allis shad in the populations.
- Produce a yearly CPUE, per SAC river (or associated estuary).
- Compare annual CPUE to the targets/limits set using data from the first six-year monitoring period.

7. Population limits or targets

7.1 Juvenile CPUE data

Population targets should be set based upon the average CPUE detected during the first six-year monitoring period. Until such time, as there are data against which to compare juvenile CPUEs, no monitoring targets can be set. Targets will be set subject to discussions between the Environment Agency, Countryside Council for Wales and English Nature regarding the data collected during the first six-year monitoring period.

In the meantime, further work is needed to investigate the relationship between adult stock size, environmental conditions and recruitment in twaite shad. This should improve current understanding of annual fluctuations in the level of recruitment, which will be essential for future condition assessments of twaite shad populations (Hillman 2002). It is important to note that failure to achieve a target level of abundance of juvenile fish in one year should not be registered as unfavourable condition because adverse environmental conditions at the time of the spawning run appears to heavily influence recruitment success.

7.2 Adult shoal counts

Population targets should be set for the number of shoals of adults observed each year during the first six-year monitoring period, at Redbrook Fish Counter on the Wye and at Nantgaredig Fish Counter on the Tywi. Until there are data against which to compare adult shoal counts, no monitoring targets can be set. Targets will be set subject to discussions between the Environment Agency, Countryside Council for Wales and English Nature regarding the data collected during the first six-year monitoring period.

Juvenile CPUE data should remain the primary indicator of population condition, although adult shoal counts should also be compared to threshold limits. Further work is needed to determine the relationship between shoal size and counter data, which may provide a means of estimating the size of the adult spawning stock.

7.3 Spawning distribution within SAC rivers

A reduction in the spawning distribution of shad in each SAC river above a set threshold will indicate an adverse change in spawning distribution. The spawning distribution should be mapped out in a comprehensive baseline survey. The absence of eggs from more than 50% of sites surveyed will indicate an adverse change in the spawning distribution in the river.

8 Environmental monitoring

Environmental information should be collected from existing Environment Agency monitoring sites. Table 3 lists the chemical and physical information that should be collected.

Table 3. Physical and chemical data that should be collected to support condition assessment of shad in SAC rivers.

Sampling parameter	Method	Typical range	Lower limit	Upper limit
Water temperature (°C)	Probe	15.0–20.0	15	–
PH	Probe	7.0–9.0	6.0	9.0
Conductivity (μS)	Probe	150.0–350.0	–	–
Water velocity (m s^{-1})	Current meter	0.5–2.0	0.5	2.0
Chloride (mg l^{-1})	Probe	10.0–30.0		
Oxygen (mg l^{-1})	Probe	8.0–11.0	8.0 (60 % saturation)	–
BOD (mg O l^{-1})	Sample	1.0–6.0	–	6.0
COD (mg O l^{-1})	Sample	8.0–30.0	–	–
Ammonium nitrogen (mg l^{-1})	Probe	0.2–0.4	–	1.3
Nitrate/nitrite (mg l^{-1})	Sample	2.0–7.0	–	–
Total phosphorus (mg l^{-1})	Sample	0.1–1.0	–	–

The Environment Agency has suitable equipment and expertise to collect data and analyse water samples. The criteria in Table 3 should be available from the monitoring department responsible for the relevant river. Electro-chemical data should be collected using a multi-functional probe (Long pers. com.). This includes: pH, conductivity, dissolved oxygen, ammonium nitrate and chloride. Other water quality data including BOD, COD, nitrate/nitrite and phosphorus should be obtained from water sampling and subsequent laboratory analysis.

Water quality data should be collected from 10 sites per SAC river, from April until September inclusive (60 samples per year). The results should be used to ensure that the water quality is of at least Water Quality Class C (in England, Wales and Northern Ireland) or B (in Scotland). In addition, water quality assessment data for the whole of the migration route should be checked to ensure that water quality is sufficient.

The Environment Agency Hydrometrics Department has suitable equipment and should be enlisted to measure the water velocity at potential upstream migratory limits. Water velocity should be measured using a current meter (Bailey pers. com.). On the Wye, Usk and Tywi there must be at least one site that is monitored every 15 minutes. Flows between April and July should not exceed 1.5 m s^{-1} in the case of twaite shad (and 2.0 m s^{-1} in the case of allis shad) for long periods on any stretch of the migration route (Maitland 2001). Data from continuous monitoring, such as at gauging stations, should be used to ensure that during the migration period flow does not exceed shad swimming capabilities.

Where discharges are made from reservoirs to the rivers Wye, Usk or Tywi, between April and July, records should be made of the discharge dates. The impacts on adult migration should be assessed in the first six-yearly report. If shad migration times are shown to avoid the periods when reservoir discharges are made, the timing of future discharges during the shad migration period should be reviewed by the relevant conservation authorities.

Water temperature in the river should be measured using Tinytag temperature data loggers. These should be present at Environment Agency gauging stations and fish counters and should be used in conjunction with water flows to provide an indication of the likelihood of shad spawning. Shad spawn when water temperatures exceed 12°C, which in Britain is typically between May and July (Maitland 2001).

Data on environmental conditions should be collated. Chemical and physical data should be checked against minimum water quality targets to ensure that water quality is favourable for shad. Measurements of water temperature and flow should be collected to facilitate investigation into annual fluctuations in monitoring results.

9 Limitations

The various monitoring methods should only be carried out when weather and river conditions permit. Juvenile surveys should not be attempted during times of high river flows, nor should fieldwork be carried out when conditions are unsafe. Risk assessments should be carried out prior to commencing any of the activities outlined in the monitoring protocol. The Environment Agency has developed generic risk assessments for seine netting and working at fish passes. Generic risk assessments for kick-sampling have also been developed by the Environment Agency. In addition to compliance with generic risk assessments, a site-specific risk assessments should be carried out prior to work commencing; potential risks at the site should be identified and minimised before proceeding with work. If risks dictate that it is unsafe to proceed and the risks cannot be reduced, then work at that site should not proceed.

The monitoring options for shad condition assessment in the UK do not include quantitative sample methods, and there is no feasible way of attaining accurate population estimates for shad in SAC rivers. Subject to further research on the River Wye hydroacoustic fish counter, it may be possible to monitor shoals of migrating shad and produce a quantitative estimate of the twaite shad population on the River Wye. Hydroacoustic fish counters are installed on the Wye and the Tywi, but there are no plans to install a hydroacoustic fish counter on the River Usk.

The best available solution is to use semi-quantitative methods that can be used to generate an index of abundance for juvenile shad, comparable between years. Seine netting for juveniles, and to a lesser extent shoal counts at fish counters, should therefore be the main methods used for shad condition assessment.

The fish entrainment data from Hinkley Point B Power Station show that levels of juvenile recruitment in shad can fluctuate considerably between years. As such, it is impractical, at the present time, to produce biologically meaningful reference points for shad populations. Aprahamian *et al*. (1998) suggested that recruitment failure in the 1980s was due to climatic factors, in which case, decreases in the size of the population were due to natural causes. With such inter-annual fluctuations to consider, it may be difficult to differentiate between population crashes and natural population troughs and peaks (Statistical tests have been implemented to ensure that adequate sample sizes are used).

10 Case study: Afon Tywi

Breeding populations of twaite shad are found in three SAC rivers in the UK: the Usk, Wye and Tywi. These SAC rivers are also designated for allis shad but they are not currently thought to support viable populations (Hillman 2002). Testing of the sampling protocol for juvenile shad recommended by Hillman (2002) was carried out on the upper river/lower estuary of the Afon Tywi.

10.1. Site selection

Six survey sites were chosen for sampling between Llandeilo and the Tywi estuary. Sites were selected based upon known spawning areas of adults, presence of shad eggs in the locality in 2002, presence of suitable juvenile habitat (backwaters and slow flowing areas) and ease of access. The survey sites were situated at Dryslwyn, Ty Castell, White Mill (all non-tidal), Carmarthen bypass, Pibwrlwyd and Coch-y-barlys (all tidal).

10.2. Sampling methodology

The sampling methodology followed the protocols developed in Section 5 using micromesh seine netting. The micromesh seine net was set from an inflatable dinghy and a minimum of three net hauls were made at each site. Surveys were carried out at the six sites from July to October 2002 inclusive. It should be noted that surveys in October involved a more concentrated effort in the lower Tywi estuary as juvenile shad generally disperse downstream at this time of year.

10.3. Results

Details of the catches from micromesh seine netting in the Afon Tywi are provided in tables 4 and 5. Catches at the three upper non-tidal sites (Dryslywn, Ty Castell and White Mill) throughout the sampling period were dominated by minnows with a single net often containing several hundred specimens (Table 4). Other species caught in lesser numbers were stoneloach, flounder, gudgeon, three-spined stickleback, lamprey, bullhead and brown trout. Catches at the upper tidal site (Carmarthen bypass) were dominated by minnows and 3-spined stickleback, and lesser numbers of flounder, gudgeon, bullhead, goby species and lamprey (Table 4). Catches at the two lower tidal sites (Pibwrlwyd and Coch-y-barlys) were dominated by goby species, with lesser numbers of bass, flounder, herring, sprat, minnow, mullet, three-spined stickleback and trout (Table 4).

Juvenile shad were only caught in surveys at Coch-y-barlys (situated on the main estuary) with two caught in September and eleven caught in October, the latter survey involving an intensive programme of 17 seine net samples. During the survey period 100 seine net samples were collected at the six sites catching a total of 32,216 fish. Hence, juvenile shad only contributed 0.0004% of the total fish catch, highlighting the difficulty in capturing the species in the Afon Tywi.

10.4. Conclusions

The sampling technique recommended by Hillman (2002) using micromesh seine netting was considered appropriate to catch juvenile shad, however, locating the juvenile nursery areas on a river catchment such as the Tywi may be problematic. Unfortunately, the poor catches of juveniles prevented the use of statistical analysis of the results. Possible reasons for the low catches of juvenile shad are poor selection of sampling sites, weak runs of adult shad into the Tywi catchment, and poor climatic conditions for spawning and recruitment. The poor selection of sampling sites was not considered a contributory cause as Countryside Council for Wales and Environment Agency surveys found shad eggs in the locality of the sites early in 2002. The very wet and cold spring and summer of 2002, and low numbers of adult shad in angler catches suggest it is the latter reasons that contributed to the poor catches of juvenile shad.

The low catches of juvenile shad created a problem with testing for condition assessment of the species in the Afon Tywi. Based on the catches from the 2002 surveys, the Afon Tywi would be considered in unfavourable conservation status, but this interpretation must be treated with caution as

Table 4. Catch details from surveys on three non-tidal sites on the Afon Tywi in 2002 (* no survey in October due to high flows).

	Dryslywn				Ty Castell				White Mill			
Species	**July**	**Aug**	**Sept**	**Oct**	**July**	**Aug**	**Sept**	**Oct**	**July**	**Aug**	**Sept**	**Oct**
Minnow (*Phoxinus phoxinus*)	718	479	531	*	283	1096	1311	*	803	2117	4003	176
Stoneloach (*Noemachilus barbatulus*)	3	29	147	*	-	7	13	*	-	2	-	1
Flounder (*Platichthys flesus*)	1	-	-	*	2	-	2	*	5	7	4	-
Gudgeon (*Gobio gobio*)	20	15	94	*	5	114	49	*	15	1	3	1
3-spined stickleback (*Gasterosteus aculeatus*)	2	-	15	*	3	5	23	*	2	17	7	-
Lamprey (*Lampetra* spp.)	2	-	-	*	-	-	-	*	-	-	-	-
Bullhead (*Cottus gobio*)	-	-	-	*	2	-	1	*	1	-	-	-
Brown trout (*Salmo trutta*)	-	-	-	*	-	-	-	*	-	1	-	2
Total	**746**	**523**	**787**	*****	**295**	**1222**	**1399**	*****	**826**	**2145**	**4017**	**180**

Table 5 Catch details from surveys on three tidal sites on the Afon Tywi in 2002 ([a]surveys in October limited by high flows, [b]surveys involved 17 nettings).

	Carmarthen bypass				Pibwrlwyd				Coch-y-barlys			
Species	**July**	**Aug**	**Sept**	**Oct**	**July**	**Aug**	**Sept**	**Oct[a]**	**July**	**Aug**	**Sept**	**Oct[b]**
Minnow (*Phoxinus phoxinus*)	2733	1958	67	418	1	1	-	1	-	-	-	894
Eel (*Anguilla anguilla*)	-	-	-	5	-	-	-	-	-	-	-	-
Flounder (*Platichthys flesus*)	365	439	27	42	32	26	6	1	30	24	8	17
Gudgeon (*Gobio gobio*)	47	-	-	-	-	-	-	-	-	-	-	-
3-spined stickleback (*Gasterosteus aculeatus*)	705	1176	123	15	-	1	-	-	-	-	-	15
Bullhead (*Cottus gobio*)	1	-	-	-	-	-	-	-	-	-	-	-
Brown trout (*Salmo trutta*)	-	1	-	-	1	-	-	-	-	-	-	1
Lamprey (*Lampetra* spp.)	-	1	-	-	-	-	-	-	-	-	-	-
Goby species (*Gobius* spp.)	-	-	1	-	127	191	-	1	983	2916	1828	4189
Herring (*Clupea harengus*)	-	-	-	-	20	32	22	-	46	53	23	15
Sprat (*Sprattus sprattus*)	-	-	-	-	-	12	14	-	12	24	10	5
Bass (*Dicentrarchus labrax*)	-	-	-	-	3	38	2	-	62	113	13	2
Mullet (*Mullus* spp.)	-	-	-	-	-	1	-	-	2	5	-	116
Twaite shad (*Alosa fallax*)	-	-	-	-	-	-	-	-	-	-	2	11
Total	3851	3575	218	480	184	302	44	3	1135	3135	1884	5265

it is based on only one year's data when climatic conditions were considered atypical. This highlights the need to monitor condition status of juvenile shad over a period of years to avoid anomalous assessment.

11 Survey monitoring

11.1 Timescale

Action	Year of monitoring programme							
	Pre	1	2	3	4	5	6	7
Fish counters								
River Wye (and Tywi) adult shoal counts	✔	✔	✔	✔	✔	✔	✔	✔
Set monitoring targets for annual shoal counts at fish counters								✔
Netting juveniles								
Find suitable sample sites, calculate sample size from confidence limits	✔							
Juvenile surveys (Calculate density, catch variance, yearly C PUE).		✔	✔	✔	✔	✔	✔	
Set monitoring targets for juvenile CPUE								✔
Egg surveys								
Comprehensive survey of spawning sites in the Usk, Wye and Tywi	✔							
Survey a proportion of the known spawning sites for presence/absence of eggs. Compare to baseline survey.		✔	✔	✔	✔	✔	✔	

11.2 Equipment and manpower implications

11.2.1 Juvenile netting surveys

Resource requirements	Manpower (person-days)
Seine netting surveys	48 (12 man days per month)
Laboratory analysis of catches and data analysis	10
Reporting	5
TOTAL	**63**

The number of survey units needed to allow statistical confidence in the data will need to be calculated based on the results of a preliminary study.

11.2.2 Fish counter monitoring

Resource requirements	Manpower (person-days)
Video analysis, data input and analysis and report writing.	1*
Data analysis and report writing.	1 per month

*Environment Agency staff routinely monitor salmonids, so the additional work needed to monitor shad is estimated at one hour per day.

11.2.3 Egg surveys

Resource requirements	Manpower (person-days)
Preliminary survey	2 person-weeks
Report writing and map creation	2 person-weeks
Routine surveys	5 person-days

12. Recommendations for reporting and key information sources

12.1 Distribution

The distribution of twaite (and allis) shad spawning sites in the Rivers Wye, Usk and Tywi, should be determined primarily by egg surveys, but also from angler catch data, fish counters and information/observations from fisheries officers. The upstream limit of migration should be reviewed in the report.

12.2 Monitoring

CPUE indices calculated for juveniles in the rivers Usk, Wye and Tywi should be compared against the monitoring target, which will be defined using data collected during the first six-year monitoring period. Juvenile surveys will be the main method for assessing the condition of shad populations in SAC rivers. Trends in juvenile CPUE indices should be discussed in relation to environmental factors, including water temperature and flow. When data have been collected for many years it may be possible to discuss the relationship between juvenile CPUE indices and the number of adult shoals detected at the fish counters.

Data from fish counters on the Wye and Tywi should be included in the report. Future research into the monitoring of shad at hydroacoustic fish counters may enable a quantitative population estimate to be obtained for the River Wye, which should be included in the six-yearly report.

Data collected by Pisces Conservation (Pisces Conservation pers. comm.) on the relative abundance of fish species entrained on the intake screens at Hinkley Point B Power Station, Severn Estuary, should be compared against trends in shad populations observed in the rivers Wye, Usk and Tywi, as measured using the methods described in the routine monitoring programme. Long-term collection of these data is recommended.

12.3 Site condition assessment

It is important that habitat quality in SAC rivers does not deteriorate. Every six years the Habitat Modification Score (HMS), derived from Habitat Quality Assessments (HQAs), should be reviewed to ensure that the river habitat quality is not declining. Once spawning sites have been identified, HQAs should be carried out every six-years at a proportion of spawning sites to check for deterioration in habitat quality.

13 Recommendations for a demographic model

There is a need to develop a demographic model for incorporation into the routine monitoring programme. Such a model could be used to predict adult return against recruitment level, on an age-class basis.

Separate demographic models should be developed for allis and twaite shad because of their different life histories. Until such time as breeding allis shad populations are identified in the UK and information about them is collected, demographic models should focus on twaite shad. Aprahamian (pers. com) found that the level of recruitment in twaite shad was directly correlated to the number of adults caught in the estuary, which suggests that a viable demographic model could be developed.

To calculate a demographic model, the following information is needed:

- Age structure of the spawning population.
- Size of the spawning population.
- Mean instantaneous mortality rate and survival rate for males and females.
- Level of recruitment per year.
- Relationship between environmental factors and recruitment.

There is no method at the present time for obtaining quantitative stock estimates for shad in the SAC rivers designated for twaite shad. The hydroacoustic fish counter at Redbrook, River Wye, is perhaps the best indication of stock size in the Wye. Future research would help to refine a routine monitoring programme.

Data from the River Wye fish counter or Severn estuary commercial netsmen by-catch makes either of these two catchments good locations from which to collect data for the development of a demographic model. Aprahamian (unpubl.) collected 17 years of data from the Severn netsmen, sampling 6125 shad. This provides a statistically reliable breakdown of the mean age structure of spawning male and female shad; it also provides a yearly index of abundance of adult shad. Aprahamian & Aprahamian (1990) also calculated the mean instantaneous mortality rates for male and female twaite shad in the Severn Estuary. Data collected at the Hinkley Point B Power Station provides a good indication of the relative strength of recruitment in the Severn each year (P. Henderson pers. com.).

In summary, a demographic model for twaite shad could be calculated using data from the Severn Estuary. This should allow an estimate of spawning stock size in year n, based on the level of recruitment in years n–3 to n–10 (Over 99% of the spawning population of twaite shad is aged between 3 and 10 years [Aprahamian & Aprahamian 1990]). The development of a demographic model should also aim to define a statistical method for assessing the sustainability of shad populations (i.e. is the population too small to be considered viable or is it self-sustaining?). This should begin with an investigation into the relationship between recruitment, adult stock size and environmental conditions.

14 Recommendations for data storage

The results of the routine monitoring programme should be systematically analysed for the rivers Wye, Usk and Tywi. The easiest way to do this is for one person to collate and analyse the data from the shad routine monitoring programme in the UK. The Environment Agency, English Nature or Countryside Council for Wales would be well placed to co-ordinate the routine monitoring programme and the storage of data. This will include the calculation of CPUE indices for juvenile netting surveys, a review of the extent of spawning in the river and the analysis of adult shoal counts from fish counters on the Rivers Wye and Tywi. All output data should be stored on the Environment Agency National Fisheries Population Database.

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Conserving Natura 2000 Rivers

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9 A Monitoring Protocol for the Floating Water-plantain, *Luronium natans*
10 A Monitoring Protocol for the European Otter, *Lutra lutra*
11 A Monitoring Protocol for Watercourses Characterised by *Ranunculion fluitantis* and *Callitricho-Batrachion* Vegetation

These publications can be obtained from:

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

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

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

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

The allis and twaite shad were once found across Europe, but populations are now declining in many areas. They are now absent from several rivers where they once supported thriving fisheries. There are now no known spawning sites for the Allis shad in the UK.

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

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

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