Monitoring the White-clawed Crayfish

Austropotamobius p. pallipes

Conserving Natura 2000 Rivers

Monitoring Series No. 1

Monitoring the White-clawed Crayfish
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Conserving Natura 2000 Rivers

This protocol for monitoring the white-clawed crayfish (*Austropotamobius pallipes*) 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 does 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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Summary

This protocol gives guidance on a new, rigorous method of selective manual survey for the white-clawed crayfish (*Austropotamobius pallipes*). It provides a basis for comparison of monitoring units over time and between rivers. The method is suitable for a range of applications, although occasionally there will be circumstances when too much of a river is unsuitable for manual survey, and other methods may be needed to supplement the standard method.

Survey forms have been developed for the standard method, but it is recommended that they are used with other methods as well. This standardisation of recording will make it easy for compilation of a national database that not only includes the general geographic distribution of crayfish, but sufficient environmental detail for comparisons to be made.

The survey method is expected to improve the limits of detection of crayfish, where manual survey is possible.

The monitoring strategy needs to provide information to determine whether a population of white-clawed crayfish is in favourable condition. This should be done both by sampling the population and by assessing any threats to the population within the catchment as a whole. Details are provided on how to sample the crayfish population, and recommendations are made on the additional data required. Where crayfish are widely distributed, it may not be possible to sample the entire length of every watercourse, but the protocol sets out a method for obtaining a representative sample.

Each river is divided into a series of monitoring units that are the basis for reporting on condition. These are usually whole tributaries, or sections of large rivers. A number of 500 m stretches are sampled in the monitoring unit. The number of stretches selected depends on the variability of the crayfish population and the precision required. Worked examples are given in the protocol, based on field-testing in the River Eden.

The required number of 500 m stretches is randomly selected from the total stretches in the monitoring unit. Within a stretch, surveyors select a sampling site (details of how to do this are included in the protocol). Surveyors then select the five areas of habitat (termed 'patches') considered to be most favourable for crayfish, and search 10 selected potential refuges in each habitat patch. The catch of crayfish is expressed as an abundance of number per 10 refuges for each site and for the series of sites within the monitoring unit.

Once the required number of stretches to be sampled in each monitoring cycle has been decided, the sampling is carried out by selecting half the stretches from those previously sampled, and half new, randomly selected stretches. It is preferable to divide the monitoring in any one unit between two or more years.

The monitoring protocol gives guidance on how the results of the surveys can be used, in conjunction with other data, for assessing the condition of the population. It also suggests how to detect degrees of change in a population that should prompt further investigation and, in some cases, management action.

1 Introduction

The white-clawed crayfish (*Austropotamobius pallipes*) is declining throughout much of its range, and is protected under both European and UK legislation (Holdich 2003). The major threats to white-clawed crayfish are a fungal disease, crayfish plague (*Aphanomyces astaci*) carried by a number of introduced North American species of crayfish, and competition from alien crayfish populations. Water quality and habitat condition are also important factors. A series of sites are being designated as Special Areas of Conservation (SACs) for the species. Biodiversity Action Plans (national, regional and local) have been prepared, containing costed actions to encourage measures for the long-term survival of the species in the UK.

By monitoring populations of crayfish, conservation agencies will study population trends, plan and prioritise river management, and assess the results of actions. The results will also be used by the UK government for a report to the European Commission on the conservation status of the species.

The protocol may also be useful in monitoring Sites of Special Scientific Interest (SSSIs) that are not SACs, and for monitoring crayfish for other purposes. The method developed as part of the protocol is likely to have a wide range of applications for surveys of crayfish in rivers, and it is hoped that this protocol will be adopted as the standard method for monitoring crayfish populations in the UK.

The aim of this protocol is:

- To provide a method for determining whether a population of white-clawed crayfish is in favourable condition in a riverine SAC.

There are essentially two main aspects to favourable condition: the abundance and health of the population, and whether there are current or future external threats to it.

There is little information available at present about long-term natural trends in populations of white-clawed crayfish. This makes it more difficult to determine whether an observed change in abundance in a population is due to natural factors or because of an external threat.

There has also been no generally accepted semi-quantitative survey method. This protocol recommends a more consistent approach to monitoring, to allow population trends to be detected. This may have wider application in a range of other rivers.

Not enough studies have been carried out in rivers of different types to be able to set targets for favourable condition based on population abundance, although this protocol gives some guidance, based on currently available knowledge. The protocol will need to be reviewed once monitoring programmes are implemented and have run for a least a full cycle of monitoring in a series of rivers.

2 Rationale for the survey method

2.1 Introduction to the survey method

The survey method recommended in this protocol for monitoring rivers is manual survey of selected habitat refuges within a site. Terms used are described in Section 4.1. The method involves selection of five patches of habitat that appear to be favourable for crayfish and can be physically searched. A search is made of 10 potential refuges in each habitat patch. The aim is to find relatively stable, individual refuges that have the highest probability of being used by crayfish.

The relative abundance of crayfish is defined as the average number of crayfish per 10 refuges searched. Details are recorded of the environmental conditions at the time of survey and the features of each patch surveyed that are most relevant to crayfish.

Where there is a relatively small, sparsely distributed population of crayfish, it is most likely to be detected by selecting the areas where conditions are most suitable and refuges for crayfish are abundant. This method essentially stratifies the in-channel habitat and deals only with the habitat most favourable for crayfish that can readily be searched in a manual survey.

The surveyor has to recognise the most favourable habitat, but field-testing has shown that surveyors can have a high degree of consistency in identifying suitable habitat, even when it is sparse.

If there is a high density of crayfish and abundant suitable habitat, the proportion of selected refuges occupied by crayfish is higher than at sites where crayfish are present, but the population is small and very patchily distributed.

This survey method is referred to as the 'standard method' in the protocol that follows. This does not mean that it is the only suitable method for crayfish surveys. Other techniques may be required for some watercourses or purposes, either in conjunction with the standard method, or instead of it. The standard method is recommended, however, wherever conditions are suitable for its use (see Section 2.2). It was designed for use in monitoring SAC rivers, but is suitable for a range of other purposes, including surveys for environmental assessment of works in rivers.

2.2 Comparison with other survey methods

Advantages and disadvantages of various survey methods for the white-clawed crayfish are outlined in Table 1.

Most SAC rivers designated for white-clawed crayfish, and many others that support crayfish populations, will have at least a proportion of their channel that is suitable for manual survey. This is so even in large rivers, where the mid-channel may not be accessible but there are often favourable areas for crayfish in the margins that can be readily searched.

The limitation of the standard method proposed in this protocol is that it requires:

- Water shallow enough for manual survey (<0.5 m).
- Reasonably clear water.
- Potential refuges that can be searched.

It cannot be used where water is always turbid, the entire channel is too deep to survey, or where the only refuges present are in the banks or other areas that cannot be surveyed.

Conditions unsuitable for survey may apply locally, over tens to hundreds of metres, but are much less likely to occur throughout a whole monitoring unit.

The standard method has major advantages over timed manual searches because it is independent of the work rate in different conditions. The number of stones that can be searched in 10, 15 or 20 minutes varies enormously, depending on the depth of water, how long it takes for the bed to clear and how much cobble and pebble lies underneath each selected stone. In addition, in the standard method, the detailing of habitat conditions in each survey patch makes it much clearer what habitat has been searched than in timed searches.

For existing monitoring programmes using timed searches it would be possible to convert to the standard method. A timed search of a site could be undertaken in the same way as previously, while recording the number of refuges actually searched. The site could be re-surveyed soon afterwards, using the standard method for comparison.

The standard method takes significantly less time than fixed-area samples and is much better suited for surveys in watercourses with moderate to low abundance of crayfish. It is therefore a better method for assessing extensive populations of crayfish at the level of the monitoring unit.

There are some benefits in fixed-area sampling, in conjunction with the proposed standard method, for detailed studies of individual sites. The best sites for fixed-area surveys are those with abundant

Table 1. Summary of methods for surveying crayfish.

Method	Requirements	Advantages	Limitations
Manual search (standard method)	Clear water up to 60 cm deep. Safe access.	Can search actual refuges. Can catch juveniles. Selective manual searching is generally the best method for preliminary surveys and whole reach surveys for baseline and monitoring studies. Can use for semi-quantitative surveys to obtain information on relative abundance and population structure, including size distribution and sex ratio.	Ineffective for searching bankside refuges or soft substrate effectively. Requires experience to identify appropriate habitats and for searching. Safety issues regarding access to water. Disturbs habitat to a degree.
Manual search (fixed-area sampling)	As above; and must also have slow flow if using enclosed quadrats.	Fixed-area manual searching in favourable conditions can give population density. More juveniles are recorded and recorded size distribution in population is closer to actual.	As above, and very labour-intensive. Requires a lot of samples. Disturbs habitat.
Trapping (baited traps)	Moderate to low flow required. Temperature above 8°C. Traps must be left overnight.	Can trap in deep or turbid water. Can record active crayfish from inaccessible refuges. Little effort required (apart from carrying traps) and may be able to work from bank only.	Low efficiency, so only suitable for populations at high abundance. Efficiency affected by many variables, so catch per unit effort unreliable. Require two visits for each survey session. Only captures active adults. High cost of traps. Risk of vandalism/loss of traps. Some risk to non-target species with funnel traps (water vole). Need to make vole-friendly traps (England and Wales only).
Trapping (unbaited traps)	Moderate to low flow required. Temperature above 8°C. Traps must be left for two or more nights.	Can leave traps out for extended periods, if stable or anchored. Can record crayfish when there are no accessible refuges for manual survey. Can catch some juveniles as well as adults. No risk to non-target species.	Need to make traps. Require two visits for each survey session. Efficiency not known. Efficiency may be affected by availability of natural refuges. Some risk of loss of traps.
Night viewing	Moderate to low flow. Temperature above 8°C. Clear water not more than 1m deep (otherwise need SCUBA and associated procedures).	Records crayfish from inaccessible refuges. Gives direct view of active animals, including behaviour. One night per session (after preliminary daytime safety check). More effective than trapping, where survey is possible. Can give abundance estimate (though only of active animals). Least disturbance as crayfish do not need to be caught (if only recording numbers and location). No risk to other species.	May not record where population abundance is low. Like trapping, affected by seasonal factors and crayfish response to environmental conditions, also behavioural response to light. Safety issues due to working at night, when obstacles on banks are less obvious. Not suitable in turbid water conditions. Not suitable for unequivocal identification of species, unless catch crayfish (in water up to 60 cm).

favourable habitat; good conditions for manual survey, notably slow flow, plus high abundance of crayfish. Fixed-area or quadrat sampling give the closest approximation to local density of crayfish, although only in the specific areas sampled. It is rarely possible to carry out sufficient sampling in all habitats within a channel to allow any estimate of average density in the whole channel. Therefore it is recommended that estimates of the total number of individuals in a stream are avoided.

The main advantages of the proposed method over night-viewing are that it is done by day and is probably better for detecting populations at low abundance. Night-viewing has been safely and effectively used in a number of studies. It has the advantage of not requiring any physical searching of refuges, and more extensive areas of channel can be covered than is possible with manual searching. However, it is affected by conditions at the time of survey and is biased towards active adult crayfish. If night-viewing is used, it is best as a supplementary method for detailed studies of individual sites.

Trapping methods are highly biased, by sex, size and environmental conditions. Trapping is also more expensive, because it requires two or more visits to each site. There are also disadvantages such as the cost of equipment, the risks to non-target species and of losing the traps. The one major advantage of trapping is that it can be done in deep and turbid water, where no other methods can be used.

Other survey methods have been used for intensive studies of particular sites. Mark-release-recapture studies can be of value in enclosed areas for estimating sampling efficiency. Often, however, recapture rates in open watercourses are relatively low and may be affected by behavioural responses. Recent work on radio-tracking has allowed investigation of the home range of individual crayfish (Robinson *et al.* 2000, Armitage 2000) and new micro-tags offer opportunities to follow individuals over extended periods. It is, however, labour-intensive and at a cost of more than £5 per tag, only suitable for detailed studies at individual sites, rather than a tool for monitoring a whole reach or watercourse.

For some rivers, and certainly in canals and still waters, other survey methods will be required. In general, however, the standard method recommended here is likely to be suitable for monitoring white-clawed crayfish in the SAC rivers and many others in the UK.

It is recommended that the standard survey recording forms are used for all crayfish surveys, whichever survey method is used.

3 Preparation

3.1 Licence

The white-clawed crayfish is protected from 'taking and sale' under Schedule 5 of the Wildlife and Countryside Act 1981 (as amended 1992). It will also be added to the Wildlife (Northern Ireland) Order 1985. A licence to handle native crayfish must be obtained from the relevant statutory agency, as in Table 2. Surveyors should apply for a licence well in advance of planned fieldwork.

All surveys must be carried out by, or under the supervision of, an experienced licence holder, and all licence conditions must be complied with.

If traps are required for crayfish survey, this requires inclusion on the survey licences. In England and Wales trapping also requires the approval of the UK Environment Agency, because traps constitute 'fixed engines' under the terms of the Salmon and Freshwater Fisheries Act 1975.

3.2 Training

All those participating in monitoring work should have been trained by an experienced surveyor and have had practice using the standard method for crayfish survey before taking part in monitoring.

For identification of white-clawed crayfish and alien species present in the UK, see Environment Agency

Table 2. Licensing authorities for the white-clawed crayfish.

Country	England	Wales	Northern Ireland
Licensing agency	English Nature (EN)	Countryside Council for Wales (CCW)	Department of the Environment for Northern Ireland (DoE NI)*
Address	English Nature Licensing Section Northminster House Peterborough PE1 1UA	Countryside Council for Wales Maes y Ffynnon Ffordd Penrhos Bangor Gwynedd LL57 2DW	Environment and Heritage Service Natural Heritage Section Commonwealth House 35 Castle Street Belfast BT1 1GU
Telephone	01733 455000	01248 385500	028 9025 1477
Email	enquiries@ english-nature.org.uk	enquiries@ ccw.gov.uk	NH@doeni.gov.uk

*DoENI deals with licensing of work on protected species – the white-clawed crayfish will be included in future.

(1999). At the start of a season of baseline survey or monitoring, it is recommended that surveyors have a day of revision in the method and familiarisation with the rivers to be surveyed to improve consistency between surveyors.

3.3 Access

Permission for access should be obtained in advance from the landowner(s). Surveyors should carry a copy of their crayfish survey licence. It is useful to have an open letter of introduction about the survey from English Nature, or another relevant agency.

3.4 Health and safety

All field survey work should adhere to health and safety procedures. Some guidance is given in Table 3. Consider the risks associated with individual sites in advance and on arrival. If in doubt about safety at a site, do not carry out the survey.

Record details on access and safety for future surveys. Useful information would include:

- Where to park.
- Route and ease of access to the site.
- Any particular hazards in the channel.

If using information from a previous site assessment, be aware that conditions may have changed since the last survey.

3.5 Preventing the spread of crayfish plague

Precautions are required to prevent the spread of crayfish plague (*Aphanomyces astaci*). All sites known to support native crayfish should be sampled with clean and dry or disinfected equipment. All

Table 3. Potential hazards during crayfish surveys and precautions to take.

Risk	Precaution
General	Always work in pairs or groups. Inform a responsible person where you are working and when you will be back. Carry mobile phone for emergency contact. Carry a first-aid kit.
Traffic hazard getting to site	Take care crossing or walking along roads. Consider using high-visibility clothing. Park your vehicle carefully to avoid causing a hazard to others.
Hostile animals or people.	Stay alert and avoid confrontation if possible. Stay calm and assertive. If a crayfish grabs hold of bare skin, don't try to pull it off. Put its body in water and allow it the option of 'escaping'. Signal crayfish in particular can draw blood if they get a grip on skin.
Slipping, falling	Banks that are steep, soft or heavily vegetated can be hazardous. They may have old barbed wire or other debris. An advance inspection of the site from the bank is recommended to identify possible hazards before entering the channel. Be cautious of submerged debris. Visibility of the bed is reduced in areas of turbulent flow. A pole is recommended for support when moving around in the channel. Be careful on slippery surfaces. Algae-covered rocks, bedrock or fords can be hazardous.
Cuts, stings, abrasion	Avoid climbing fences; use stiles or gates where possible. Be aware of vegetation and avoid low branches, etc. Be aware of possible sharp objects in the water. Wear thick-soled boots and consider wearing protective gloves, especially in urban areas.
Risk of drowning	Always check for current speed, channel substrate and depth before entering the water. Use a pole or stout stick to check wherever necessary. Do not enter channel unless you are sure it is safe to do so. Waist or chest waders are hazardous if they fill with water and encourage wading in deep water. Thigh waders or a drysuit are preferable. A life jacket is recommended, especially when wearing waders or when there may be areas of deep water.
Risk of strain injuries, bruising, or trapping fingers, hands, or feet	Use both hands to turn large stones. Turn large stones rather than lifting them. Do not over-reach. If in doubt about the weight of a stone, or if a stone is deeply bedded, leave it. Crayfish cannot use refuges under deeply bedded stones, anyway. Check that feet and hand are safely out of the way when moving stones. Searching is usually done by bending or crouching. Change position frequently and do stretches of back and limbs at the start and between sessions to avoid or reduce strain or fatigue.
Hypothermia and fatigue	Be aware of the signs of hypothermia. Stop and take action to warm up immediately if feeling chilled. Gloves help to reduce heat loss, but hands may be immersed for prolonged periods. Carry sugary snacks and drinks. Be especially careful about fatigue when water or air temperature is 10°C or less, and if doing night viewing. It is advisable to carry out manual searching for no more than one hour without a break (this may be an issue when doing fixed-area sampling, but is not likely to occur with the standard method). Be realistic about how much survey can be done in a day. If night viewing, do not extend a survey session beyond three hours in total.
Disease	Be aware of the risk of Weil's disease and other waterbourne diseases. Use of rubber/latex gloves will reduce the chances of cuts and abrasion during manual searches. Consider using a barrier cream before surveying. Clean and cover any cuts or abrasions with waterproof dressings. Clean hands with wet-wipes or similar before eating and at the end of each survey.

equipment used at sites known to contain signal crayfish or other alien crayfish must be disinfected and dried out thoroughly before it is used at other sites. Additional details are given in Appendix 2.

If a catchment has a population of signal crayfish (*Pacifastacus leniusculus*), it is preferable to survey any areas that only have white-clawed crayfish prior to those known to have alien crayfish.

These hygiene procedures should also be impressed on any person or organisation that may potentially transfer plague. This includes those carrying out surveys in rivers for other purposes. In the event of crayfish plague being detected, all access to the affected river should be avoided if possible and disinfection procedures should be rigorously followed where access is essential.

3.6 Timing and conditions

The recommended period for carrying out surveys for native crayfish is May to October inclusive. The optimum time is from July to September, after the crayfish have released their young. In southern England all white-clawed crayfish may have finished breeding before the end of June. In northern England, some crayfish may have young up to the end of July.

Do not survey during increasing or high river flow. In addition to the issue of personal safety, crayfish tend to stay in their refuges and are harder to find. Areas of the channel occupied by crayfish may become too deep to survey, and recently covered margins may not have any crayfish at all. The water may also be too turbid. Manual surveys have poorer results when the water temperature is less than 8°C, as crayfish are less active and deeper in their refuges, hence the recommendation for surveys during the summer.

Trapping or night viewing are ineffective in cold conditions and at any time when flow is increasing.

3.7 Equipment

The equipment required for a crayfish survey is detailed in Table 4. Some items can be shared by two surveyors, but each individual will require personal protective gear and a viewing aid as a minimum.

4 Monitoring protocol

This section starts with an outline of the terms used in the protocol, then deals with the following stages of developing a monitoring programme:

- Preparing for a baseline survey.
- Selecting stretches for sampling sites.
- Survey method on site.
- Analysis of data.

4.1 Terms used

Different scales need to be considered in the monitoring strategy. At the highest level, there is the catchment, where a range of factors may affect the suitability of a river for white-clawed crayfish. These include:

- Alien crayfish.
- The risk of crayfish plague.

Table 4. Surveyors' checklist (the most essential items are shown in bold).

Standard recording forms (waterproof paper is useful).
Waterproof clipboard and pencils.
OS map (OS 1:2500 or 1:10000 scale preferred), also River Corridor Survey drawing if available.
Copy of crayfish licence, personal ID and/or letter of introduction, details of local contacts.
Hand-held Global Positioning System (recommended, even when maps are available).
Camera (digital recommended, or 400 ASA film).
Viewing aid – essential for rippled surface. Best by far: a small wooden drawer fitted with a clear plastic bottom sealed with mastic; it floats without tipping. Other options bucket with clear bottom, small plastic fish tank, etc.
Vernier gauge callipers (plastic to 1 mm accuracy is adequate - some callipers may read to 0.1 mm, but surveyors can only measure live crayfish to nearest 0.5 mm at best).
Thermometer (recommended on a string).
Hand net (recommend plastic aquarium net 15 x15 cm square, black mesh, 15 cm deep or more, short handle about 50 cm – this is much better than the standard Freshwater Biological Association net).
At least one bucket or other container for temporarily holding crayfish. A viewing drawer can hold the catch. An open-weave fabric bag can be used in addition. Need to have the catch from a patch in one container and crayfish after individual recording in another prior to release back to the patch.
Waterproof torch (optional for daytime, but may be useful in shady sites; plus spare batteries in waterproof bag or box).
Waders (thigh) or drysuit; life-jacket recommended.
Rubber gloves (recommended to reduce abrasion and heat loss, although they will fill with water).
Staff or ranging pole for use when wading and to measure depth in cm.
Mobile phone (recommended for emergency use and call-in procedure).
Wet wipes or other personal disinfectant, also basic first aid kit, including waterproof plasters.
Food and drink, including emergency snacks.
Bottle of bleach or iodophore for disinfecting gear (essential). Also recommend shallow basin or tray and plastic brush for scrubbing down boots and gear – at car, not on riverbank.
Towel for drying hands during survey; a hat (sun hat improves viewing in bright conditions, warm hat helps reduce the 20% body heat loss via head); spare clothing for warmth, or if you get soaked during survey.
Compass, tissues, penknife, string, sunscreen, insect repellent, survival bag (no specific requirement, but may come in handy).
Rucksack or shoulderbag to carry the gear.
If doing fixed-area sampling, add quadrat and/or marker pegs, and preferably include a mesh or net surround for fixed-area samples, to avoid escapes.

- The risk of pollution.
- Land use, erosion and siltation, and nutrient loading.

These factors are discussed in Section 7.

Populations of crayfish may vary considerably in different tributaries. River systems can be subdivided into monitoring units for the purpose of condition assessment. River SSSIs and SACs may be divided on the basis of major tributaries, designated for one or several features, including white-clawed crayfish.

The monitoring units tend to have a geomorphological basis, reflecting major changes in gradient, geology and flow. A method for subdividing rivers into Evaluated Corridor Sections (ECSs) has been developed in Scotland as part of the SERCON methodology (System for Evaluating Rivers for Conservation) (Boon *et al*. 1996). Another simplified method of dividing rivers into geomorphological reaches is being developed by the Environment Agency in England and Wales.

For this protocol, a monitoring unit is defined as any length of river for which an estimate is required of crayfish presence and relative abundance, although it will usually be at least 10 km in length.

Stretches of river 500 m in length are used for selecting sites to survey. They may be 500 m sections previously surveyed using the Environment Agency's River Habitat Survey, but any randomly selected stretches can be used. The sampling site is a short length of river where the crayfish survey is carried out, usually 100 m, but may be 200 m in large rivers.

The habitat patch is an area within a sampling site that a surveyor decides has a suitable combination of in-channel habitat and flow conditions to support crayfish. The size of the habitat patch may vary, but is not less than 1 m^2 and may be up to about 20 m^2.

The individual refuge within a patch is the basic unit of survey. It is usually a boulder (>25 cm) or large cobble (15–25 cm). It may be any other feature that offers relatively stable shelter for one crayfish, or sometimes several, such as a block of rubble, an old tyre or even a large lump of clay.

Figure 1 shows the progressive change in scale, in five schematic drawings from catchment to crayfish.

4.2 Preparing for a baseline survey

Before starting a baseline survey for crayfish determine:

- Current known distribution of crayfish in the monitoring unit and catchment from existing records, both for white-clawed crayfish and aliens.
- Chemical and biological water quality.
- Calcium concentration (if watercourse is unsurveyed).
- Available coverage of River Habitat Survey or River Corridor Survey (optional).

In catchments where white-clawed crayfish are known to occur, all reaches or monitoring units should be included in the baseline survey, except where conditions are clearly unsuitable for crayfish.

Grounds for excluding reaches from survey are:

- Biological and/or chemical water quality of Grade D (poor) (Environment Agency classification).
- Calcium concentration less than 5 mg l^{-1} (as Ca_2CO_3).

4.2.1 Aliens

The presence of alien crayfish in the catchment will necessitate disease precautions. The information is also relevant to the conservation status of white-clawed crayfish.

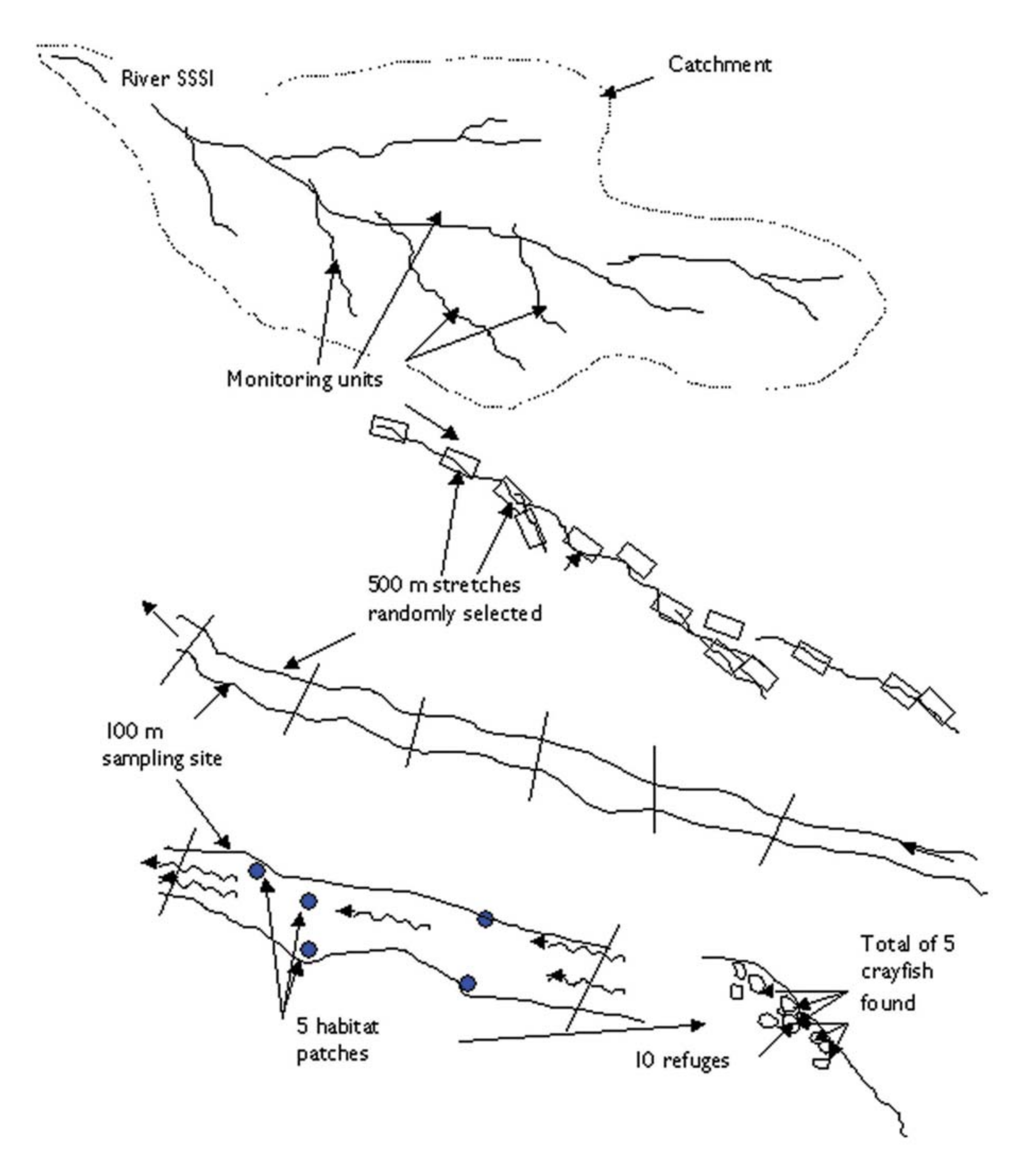


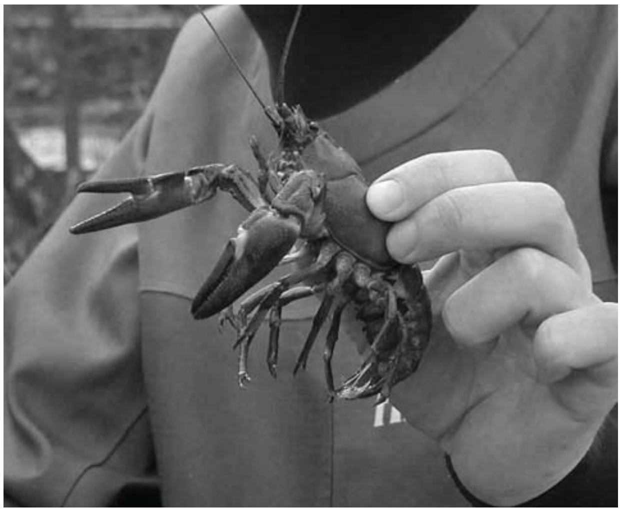
Figure 1. Schematic diagram of monitoring protocol.

4.2.2 Water quality

Most populations of white-clawed crayfish are found in water of Grade A or B, but can occur in watercourses with water of Grade C (Fair). Grade C water may have low population density and is unlikely to have white-clawed crayfish unless the species is also present upstream. Some species of alien crayfish are more tolerant of fair to poor water quality and eutrophication. A crayfish survey may therefore be appropriate in lower grades of water, either to determine the geographic limits of a population of white-clawed crayfish, or to investigate whether alien crayfish are present.

4.2.3 Habitat

River Habitat Survey (RHS) is a database system developed by the Environment Agency in England and Wales. Certain attributes of the channel structure, flow and habitats are recorded for 500 m sections of river. RHS may be of use for indicating stretches that are more difficult for manual survey, although a crayfish survey may still be feasible. RHS is at a very coarse scale compared to the level of habitat patch in a crayfish survey, and is therefore not a good predictor of crayfish presence or absence.



Environment Agency

The North American signal crayfish is a carrier of plague, and its presence in a catchment will necessitate disease precautions.

River Corridor Survey (National Rivers Authority 1992) is more useful to crayfish surveyors. This is a drawing-based survey that indicates the location of features such as riffles, pools, bankside trees, aquatic vegetation and channel profile within a 500 m section. It will not identify areas with favourable habitat patches in any detail, but will be of value in planning access to the stretch and sites within it, if it is available.

4.3 Selecting stretches for sampling sites

The recommendation is to survey only one sampling site in any selected 500 m stretch, because the variation between stretches is greater than the difference between sites within a single stretch.

In catchments where only small, localised populations are known, it may be feasible to survey at least one sampling site in every 500 m stretch.

In catchments that still have abundant white-clawed crayfish, mainly in northern England and in Northern Ireland, there are unlikely to be the resources available to survey the whole extent of white-clawed crayfish populations. For extensive populations, a number of stretches need to be selected and one sampling site chosen in each of these. In these catchments, crayfish can be expected to colonize all areas that have suitable physical habitat, unless there is a physical barrier to their movement, or adverse factors such as pollution.

Physical barriers to white-clawed crayfish may include major waterfalls, large dams or weirs, long culverts, flat sheets of bedrock with undercut step falls, and fords with an overhang. These features may be a barrier to white-clawed crayfish, but may not prevent colonisation by signal crayfish, as they can climb well and walk overland.

Unless the reach or monitoring unit is very short, the number of samples required does not depend on the proportion of the total length that is sampled, but on the likelihood of finding crayfish.

The standard method was tested in two tributaries of the River Eden in 2002. Details of the statistical modelling carried out for Scandal Beck and the River Lowther are given in the fieldwork report (Peay 2002). The number of samples required to estimate the mean abundance of crayfish in a monitoring unit or reach, can be calculated for a chosen degree of precision, provided the variance between 500 m stretches can be estimated. As the number of stretches sampled within a monitoring unit increases, the mean abundance of crayfish approaches a log normal distribution.

There is relatively little information as yet about the variation in abundance of crayfish in other types of river. An example of an extensive survey in a lowland river is given in Box 1. Before a baseline survey is carried out, there will often be little or no information about how variable the crayfish population is and hence the number of sites required.

At present it is only possible to make a recommendation based on what is known. Using the Eden

Box 1. Example of an extensive baseline survey and the probability of detecting crayfish.

AERC (2000) did a survey of three lengths of the upper River Witham, near Grantham, Lincolnshire, a lowland river, where the substrate is predominantly sand and gravel, clay or silt. In all, the surveyors covered 48 sections of 500 m, subdivided into 100 m subsections; 240 in total. Each subsection was surveyed by a short search of stones or other refuges, supplemented by netting of vegetation in those areas too deep for effective manual searching. Timing was not recorded for each subsection, but was not more than 20 minutes. Selective manual searching and sweep-netting were used. Surveyors apparently searched one area of habitat per subsection.

If subsections too deep for effective searching are omitted, the probability of a surveyor finding a crayfish at a number of randomly selected 100 m sites can be modelled as follows:

No. sites selected at random	Mean total no. of crayfish found from all the sites sampled	95% confidence limits	Percentage no. crayfish
5	12.2	2, 25	0.66
10	24.7	9, 42	0
20	49.3	28, 72	0

This means if a selection of five 100 m sites were sampled on this river, a total of about 12 crayfish would be expected to be recorded on average, for this level of survey effort. The number might range between two and 25. There is less than a 1% chance of finding no crayfish under these conditions.

The survey shows the value of concentrating on habitats that can be searched effectively. Wherever possible, the surveyors searched individual refuges, mainly stones, although occasionally logs or debris. They only reverted to sweep-netting of vegetation where manual searching was not possible, usually due to depth. Of the 131 subsections found to have crayfish, sweep-netting was the method used in only 19 of the subsections, 14% of the total. Sweep-netting accounted for 7.2% of the catch (34 crayfish of 472 recorded.). The survey showed there were plenty of subsections suitable for manual survey, even in a lowland river with relatively little cobble and boulder substrate. For monitoring the River Witham, all the sections that were too deep for efficient manual survey could be omitted, as could sweep-netting as a survey method. Using the recommended standard method of manual survey would provide better estimates of relative abundance.

tributaries as examples, the recommendation for a baseline is to survey at least 8 sites in each monitoring unit or reach, and preferably to survey 16 sites or more.

Section 4.5 describes how to select the number of samples for monitoring once a baseline survey has been undertaken.

Past surveys for crayfish and *ad hoc* records are often only available from easily accessible sites. This information can be useful for indicating the presence and general geographic distribution of crayfish. Nonetheless, use of stretches and sites selected on the basis of access is not recommended for a monitoring programme, where the intention is that sampled sites are representative of the monitoring unit as a whole, or at least the 'surveyable' sites within it. Bias introduced by choosing for ease of access may go undetected for a long time.

To be representative of the monitoring unit, the selection of stretches should be random, rather than based on ease of access. Surveyors can chose the site sampled within the stretch, however.

If available, previously surveyed River Habitat Survey sections could be used as stretches for crayfish surveys. This is simply for convenience, as RHS sections will have been randomly selected. In addition, details on obtaining access to the site may already be available.

4.4 Survey method at a sampling site

4.4.1 Finding a site within a 500 m stretch

The size of the watercourse affects the scale at which physical habitat features occur. In a small, stony watercourse, any 100 m length is likely to have several bends, riffles pools, and variations in the banks. In a large river, 100 m may only have part of the variation found in the reach – for example, it may be all glide, with no riffle, or the converse. Additionally, in large rivers there may be access only in the margins, or from one bank, or to other localised areas of the river. Site length can be increased to 200 m, or up to 400 m in exceptional cases.

The standard method requires random selection of 500 m stretches, but surveyors select one site to survey within each stretch. The length of survey sites is generally 100m, but can be varied depending on the scale of the river.

Within a randomly selected 500 m length of watercourse, the procedure is as follows:

- Walk to the downstream end of the 500 m stretch.
- Assess the channel conditions in at least the first 100 m, for suitability to survey, considering access from the banks, flow, channel depth and potential hazards.
- Look for potential habitat patches, identifying the five most favourable looking and surveyable patches in the first 100 m. Patches are unlikely to be evenly spread within the site. They may be clustered in the most suitable areas – for example, four of five might be in two areas of glide totalling 40 m. Patches should be at least 5 m apart. A habitat patch might be as little as 1 square metre, or a narrow upstream strip up to about 10 m length.

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When surveying a watercourse for crayfish, check all areas of the channel with preferred features. Crayfish look for refuges that are stable and resist fast flows, with clear water and boulders larger than 25 cm across.

Table 5. Crayfish habitat preferences – a guide to identifying habitat patches and refuges.

Crayfish strongly prefer	more than	much more than (or avoid)
Boulders (>25 cm), stone or other material >	large cobbles (15–25 cm) >>	small cobble (6–15 cm)
Slow-flowing glides and pools (provided there are refuges) >	riffles >>	high-energy areas such as rapids (avoided).
Localised velocity of 0.1m s^{-1} or less >	less than 0.2m sec^{-1} >>	more than 0.2 m sec^{-1} (avoided).
Boulders or large cobbles in groups with crevices between them >	isolated large stones on smaller substrate such as pebble and gravel >>	a lot of small stone (small cobble and pebble).
Deep crevices in bedrock (can't usually search) >	partly flattened boulders and large cobbles >>	high-sided, rounded cobbles (more easily rolled in spates).
Underlying substrate of fine gravel/sand with some pebbles >	pebble and coarse gravel >>	clay.
Loose boulders	>>	deeply bedded boulders in a compacted bed (not accessible to crayfish).
Submerged refuges in stable banks (e.g. natural crevices, stone block reinforcement or stable, slightly undercut banks with overhanging vegetation, large tree roots, etc.)>	refuges in the slow-flowing margins >	refuges in mid-channel (especially if flow is a run or higher energy).
Margins next to favourable bankside habitat >	margins where adjacent banks have no scope for refuges (e.g. shallow slopes) >>	margins where adjacent earth banks are slumped and actively eroding.

- Within each patch select 10 potential refuges.
- If there are some patches that are suitable for survey, but fewer than five, extend the sampling site to 200 m and select what appear to be the best five patches in 200 m.
- If there are fewer than five habitat patches worth surveying in 200 m, start at the next 200 m site upstream and search for five patches in this site.
- Record the location of the site using GPS.
- If there are still fewer than five habitat patches, retain the results from any patches that have been surveyed and complete the evaluation of crayfish habitat for the 400 m inspected.
- If the whole channel in 400 m is unsuitable for survey, complete the assessment on the habitat record sheet and go to another 500 m stretch.

4.4.2 Identifying good refuges for crayfish

The key features of potential refuges for crayfish are that they are:

- Big enough to amply cover the crayfish.
- Relatively stable and resistant to high flows.
- In flow that is slow enough for a crayfish to walk in it.
- Not too silted.

Foster (1993) showed that the use of refuges is related to body size. This has been confirmed by many other studies. Crayfish prefer large refuges to a much greater extent than could be accounted for simply by avoiding predatory fish. The ability of refuges to resist movement during spates is a very important factor. Crayfish take avoiding action as soon as there is any increase in velocity in a watercourse. The need for security in floods is especially important in relatively high-energy, stony watercourses, but it applies to all crayfish populations in watercourses. In general, crayfish have habitat preferences, as shown in Table 5.

Look for areas of the channel with preferred features. Not all characteristics are obvious from a distance. For example, boulders in a slow glide may all be too deeply bedded in sand for crayfish to have access underneath. Cobbles and rubble tipped on the outside of a bend to prevent erosion may offer abundant crevices for crayfish, but the material may be piled so deeply that it cannot be searched effectively.

If surveyors need to vary the number of refuges or patches for any reason, this should be carefully recorded on the habitat record sheet.

Additional details on how to carry out a survey are given in Appendix 2, and recording forms are in Appendix 1.

4.4.3 Limits of detection

The lowest recordable level of abundance is 0.02 (1 crayfish from 50 refuges) although the probability of finding at least one crayfish at this abundance is 0.63. The true abundance has to be below 0.014 (1 in 71 refuges) before there is less than a 50% chance of finding a crayfish. The lowest actual abundance with a high (90%) chance of recording a crayfish is 0.046 (1 crayfish from 22 refuges). There is only limited information about the limits of detection in terms of population density in fixed areas. Nonetheless, current indications are that it is probably around 0.2 crayfish per square metre.

4.4.4 Recording survey details

The survey record consists of the following:

- Basic survey details, including conditions at the time of survey.
- Habitat details in each habitat patch.
- An overall appraisal of habitat for crayfish and ease of survey in the site.
- Crayfish record, the details of the catch.

Appendix 1 includes two survey forms – one for survey details and habitat, the other for the catch of crayfish. Instructions on the completion of the forms are included. The forms are available on the website (www.riverlife.org.uk/species/crayfish.html) as spreadsheet files.

A photograph should be taken of each site, facing in an upstream direction, from the start of the area in which habitat patches are surveyed. The aim is to show the character of the sampling site. Photographs may also be taken of any features of particular interest, such as individual habitat patches, or problems such as bank poaching. Flash photography is best avoided, especially for details, as light reflected off the water will cause loss of any details of the substrate.

Locations of photographs should be referenced on the survey sheet, by description or by annotating a map. If required, record the location with handheld GPS.

Presence of bullhead (*Cottus gobio*) has been included on the recording sheet. The bullhead is another species included in designation of SAC rivers. There is a separate monitoring protocol for this species (Cowx & Harvey 2003), but there is the option of recording it here. Bullhead use very similar refuges under stones to those used by white-clawed crayfish. Where bullhead are present conditions are usually suitable for crayfish too. A site with abundant bullhead but few or no crayfish may sometimes indicate a problem, for example a previous pollution incident.

A summary evaluation of crayfish habitat is recorded for the whole site on a qualitative scale. A surveyor can indicate whether the amount of habitat searched is most of the favourable habitat for crayfish present, or only a small proportion of it. Additional notes should be made on the survey form. This will help in the interpretation of the results of surveys.

Surveyors should not leave a site without checking that all the information to be recorded has been completed in full.

In complex watercourses with a lot of variation in substrate, channel features and flow conditions, it would be too time-consuming to map the habitat in sufficient detail to be useful for repeat surveys. In addition, the in-channel habitat would be subject to natural change over time, especially in active, stony streams. Nonetheless, where the patches suitable for searching are few and localised, especially on the larger rivers, it may be useful to record the location of patches surveyed. Use GPS, annotation on OS maps and/or descriptions of location relative to fixed features such as bridges or boundaries.

For special studies where sites are being used for annual monitoring or supplementary fixed-area sampling, it may be of value to prepare a detailed site map. This can be recorded in the style of a River Corridor Survey (NRA 1992), but at the scale of site used for the crayfish survey (100 m rather than 500 m). Additional notes should be added to the drawing on the features of most importance for crayfish, with photographs as appropriate. If used, mapping should be suitable for scanning and subsequent use on GIS, and should be updated as necessary on subsequent site visits.

If any methods of survey are used in addition to the standard method, the catch by different methods must be reported separately. Never aggregate numbers of crayfish caught by different methods to give a spurious total.

4.5 Statistical analysis of relative abundance data

The results from the baseline survey of a monitoring unit can be used to determine how many sites should be monitored over time, using the method described below.

Having collected survey data on stretches on a river, one site per stretch, the first step is to calculate the number of crayfish per 10 refuges for each individual site. A mean abundance for the monitoring unit or reach can then be calculated. A confidence interval can also be found for this mean.

To do this, find the mean for all the stretches sampled in the monitoring unit or reach and the standard deviation of these means. A 95% confidence interval for the monitoring unit mean abundance is then:

(observed mean $\pm\ t_{n-1,\,0.975} \times sd/\sqrt{n}$).

- Here sd is the standard deviation of the stretch means
- n is the number of stretches
- $t_{n-1,\,0.975}$ is the 0.975 percentile of the t distribution with n–1 degrees of freedom.

Box 2 shows a worked example from the testing of the monitoring protocol on two tributaries of the River Eden in 2002. It shows the calculation of the confidence limits for the mean abundance of crayfish in a monitoring unit, and how this can be used to determine the number of samples required in a monitoring programme, depending on the number of samples required. In these watercourses it would require a very large number of samples to obtain confidence limits to within 40% of the mean abundance for the monitoring unit.

Box 2. Analysis from crayfish survey of two tributaries of the River Eden.

For the trial data from two of the River Eden tributaries, a test was undertaken based on the bootstrap simulation (described in the fieldwork report, Peay 2002). For the test the assumption is made that 16 samples were taken, one in each stretch. In fact, many more sites were sampled during the surveys, although there is no significant difference in the standard deviations if the actual means per stretch are used.

The standard deviation of the stretch means is coincidentally about 3.4 for both Scandal Beck and the River Lowther. The means are 5 and 3 respectively, and $t_{15, 0.975} = 2.13$. Thus a 95% confidence interval for the mean count per 10 refuges in the Lowther would be 3 ± 2.13 x 3.4/4 that is, (1.2,4.8). For Scandal Beck it would be 5±2.13 x 3.4/4, that is (3.2,6.8). Note that the degrees of freedom are calculated from the number of stretches, rather than, for example, the total number of refuges, since there will be a large within-stretch correlation in the counts. For the same reason the standard deviation is calculated from the stretch means rather than, for example, the patch means. Note also that there is no significant difference between the two rivers.

It is possible also to determine the number of samples required to estimate the mean to a required precision. At present there is very little information about the between-stretch variance in any rivers other than the two in the trial. However, we could make the assumption that the coefficient of variation (cv, the ratio of standard deviation to mean) is 3.4/5 = 0.68 in rivers 'like Scandal Beck', and 3.4/3 = 1.13 in rivers 'like the River Lowther'.

The t statistic is close to 2 for reasonably large numbers of samples, and so we can write a 95% confidence interval as mean ± 2 x mean X cv/◆n. Thus, if we want the end points of the interval to be within X% of the mean, we need (2 x cv x 100)/un = X. Rearranging this, the number of samples (n) required for a monitoring survey can be calculated as follows, for any selected value of X: n= (2 x cv x100) /X)2.

This means, for example, if it was decided that nine sites on Scandal Beck were to be monitored in each reporting cycle, the confidence interval on the mean abundance for the monitoring unit would be within 45% of the mean. The same number of sites sampled in the River Lowther would give confidence limits within 75% of the mean. If the number of sites monitored was increased to 16, the confidence limits would be within 34% of the mean abundance for Scandal Beck and within 57% of the mean for the River Lowther.

The required number of sample for the two river types, for different levels of precision (X) are as follows:

No. of sample sites required

X	**Lowther**	**Scandal**
10%	511	185
30%	57	21
50%	20	7
100%	5	2

In practice, there are unlikely to be the resources for very high levels of precision. Nonetheless, even with fewer samples, it should still be possible to adequately address the two main purposes in recording the relative abundance of crayfish:

- To assess whether the population is in favourable condition at the time of the survey
- To determine whether there is any significant change over time.

The ability to detect change in abundance is discussed in Section 5.1.

4.6 Analysis of crayfish catch

Recommendations for analysis of data are as follows:

- Crayfish abundance per site, as no. crayfish per 10 refuges and average abundance per monitoring unit with confidence limits.
- Geographic distribution of crayfish within the monitoring unit. Show sites and abundance on a scale of distance upstream on a chart or map.
- Size distribution of population. This reflects the results of using the survey method in healthy populations, but may also indicate if populations are recovering or colonising.
- Percentage of population as juveniles less than 25 mm carapace length (CL).
- Health of population, percentage population with thelohaniasis (porcelain disease).
- Percentage of adult females showing signs of breeding. This is only an indication of population health, so no targets can be set because the evidence of breeding varies during the summer season.

A report detailing the results should be produced after each survey.

Copy all completed survey record forms to the local offices of English Nature and the Environment Agency in England, (or other country agencies as applicable). Survey record forms should also be copied as spreadsheet files to the national database, as soon as this is available. Currently, the Biological Records Centre, Monks Wood, Cambridgeshire, holds all the pre-1996 records that were compiled in a database by Nottingham University for the Environment Agency, plus available data from Northern Ireland. Recently, the Environment Agency has been collating records up to 2001, (Sibley *et al.* 2002). An atlas of the distribution of crayfish species in Europe, including the British Isles, will soon be started with European Commission funding, under the CRAYNET programme fronted by the University of Poitiers, France (DM Holdich, pers. comm.).

For consistency, all crayfish surveys should be recorded using the standard survey forms, whichever survey methods are used.

This standardisation of recording will make it easier for compilation of a national database that in future includes both the general geographic distribution of crayfish, but also sufficient environmental detail for comparisons to be made between sites surveyed by the same method.

Health and safety are always important considerations in any field survey. Surveyors should make notes on access to sites and potential hazards as a guide for future surveys, although conditions may change over time.

4.7 Other information relevant to determining favourable condition

The report on the status of white-clawed crayfish in a monitoring unit should include details of the presence of adverse factors in monitoring unit and current trends or threats if known. The key factors are alien crayfish, crayfish plague, water pollution, excessive erosion or siltation and possibly floods. Other factors may be relevant locally. These are discussed in more detail in Appendix 4. Data that may be relevant to determining whether a population is in favourable condition are summarised as follows:

Aliens

- Distance (in km) to nearest known alien crayfish population, by water and over land.

Risk of crayfish plague

- Number of angling clubs fishing the watercourse and approximate membership.
- Number of angling clubs on watercourse also holding rights to waters with alien crayfish.
- Number of clubs stocking fish from fish farms or other waters with alien crayfish (note that, in England and Wales, a policy of no stocking from catchments with alien crayfish has been agreed).

Fish stocking

- Details of stocking with fish species at high densities (predation risk).
- Number of fish farms in the catchment with inadequate screening to prevent escapes.

Risk of pollution

- Number of farm holdings in catchment/sub-catchment classed as having high or moderate risk of pollution from sheep dip or other operations.
- Pollution incidents within the past 10 years; date, type, source if known and lengths of watercourse affected by recorded or suspected pollution, including recorded incidents and changes in biological water quality.

Land use, erosion and siltation

- Riverside land use (percentages by category).
- Riverbank fencing – fenced grassland (m/km both sides and percentage).
- Eroding banks – types (m/km both sides and percentage).
- Other types of bank modification (proportion of modified banks by type, and whether favourable/unfavourable to crayfish).

Flood events

- Date of flood events.
- Geographic limits of perennial flow, if applicable.

4.8 Other sources of information on crayfish populations

If engineering works are required in any rivers with white-clawed crayfish, take the opportunity to obtain population data. Recommendations are given in Box 3.

Box 3. Making the most of essential engineering works.

In any SSSI, there is a presumption against any works that might damage the interest of the site. Nevertheless, engineering works are sometimes required in rivers. In rivers with white-clawed crayfish, at any sites where engineering works necessitate drainage of a section of watercourse, or disturbance of the banks, the opportunity should be taken to obtain information about the abundance of crayfish before, during and after works. Information of this type improves understanding of survey efficiencies and population abundance. Even de-watering does not provide an absolute population density, however, as efficiency of rescue varies and juveniles tend to be under-recorded.

Carry out the standard survey method in advance of works. Depending on the nature and extent of the works, additional survey may be appropriate, using fixed-area sampling, night-viewing and/or trapping. Take photographs. A habitat map targeted to white-clawed crayfish may be useful. Submit all results of baseline survey to the relevant conservation agencies before the start of works on the site.

Proposed mitigation measures should include details of work, how crayfish will be protected and how the watercourse will be reinstated. Any works that could affect white-clawed crayfish should be undertaken by or under the supervision of a licence holder. Details of works, area, methods used and crayfish removed should be recorded, as they actually occurred, even if this was not as initially planned. An estimate should be made of the crayfish density in any area that is dewatered. In addition to the report on any crayfish rescue, details should be provided to the conservation agency of the reinstatement of the watercourse, including photographs.

Monitoring crayfish after works should form part of the project. Surveys should be carried out using the standard method at the site or sites affected by works and any additional methods agreed. See Peay (2000) for additional guidance on works affecting white-clawed crayfish and Peay (2003b) for more on crayfish habitat, including restoration.

5. Monitoring strategy

5.1 Detection of change

At present there is only limited information about the way populations of crayfish vary in abundance and spatially over time. For example, it is possible that the mean abundance in an individual stretch may change over time, while the overall mean does not change (the population might move within the reach according to changing conditions). This makes it difficult to estimate the power of the monitoring strategy (the probability of detecting change).

Repeat sampling some stretches from one monitoring round to the next will improve the chance of detecting a change if the change is consistent along the reach (that is, all stretches change by the same amount), but not if there is spatial change in the population. The 'worst-case' scenario would be that the stretches are effectively independent in time. While this is possible, the factors most likely to affect the abundance of crayfish will tend to operate in more than one stretch – for example if the population is affected by a major flood, drought, outbreak of disease or serious pollution incident. White-clawed crayfish appear to stay in an area unless conditions become unfavourable. Reduction of the quality of habitat in parts of a stretch, for example due to a flood event, might cause a localised reduction in abundance, but this type of change would be detected by surveyors.

It is possible to make some informed guesses about the probability of detecting change. Box 4 shows the example of Scandal Beck and River Lowther (used in Box 2) and indicates the power of monitoring surveys to detect change with different numbers of samples.

There are few monitoring studies of crayfish in the UK that have been done annually over a number of years. One such is the example outlined in Box 5. Although some sites have considerably more habitat for crayfish than others, and this is reflected in the results each year, the average abundance in the reach remained relatively constant from year to year during the period of monitoring.

It is not known how a population of crayfish varies over longer periods of time. There may be large natural fluctuations in the abundance of crayfish. For example, unexplained mass mortalities have been recorded in two different rivers in East Midlands on the same day. These were not attributable to crayfish plague or pollution and the cause is unknown, although moulting stress during certain environmental conditions has been suggested as a possible reason (DM Holdich, pers. comm.). By contrast, there are reports that the crayfish population in the Yorkshire Ouse rose to high abundance over several years, sufficient to be noticed by anglers, but then fell to much lower abundance (PD Hiley, pers. comm.).

Information on long-term variation will gradually be obtained from the monitoring of crayfish populations in SAC rivers and from other studies.

5.2 Monitoring cycle

The following points recommend an approach to monitoring crayfish populations in rivers:

- The monitoring cycle for reporting on the features of SAC is six years. The guidance given by the JNCC on common standards for monitoring SSSIs and SACs (JNCC 1998) is that any round of monitoring should be completed within a three-year period. This means that if the first round of monitoring starts in Year 1 it must finish in Year 2 or 3, and a second round of monitoring should start in Year 7. Monitoring for other purposes may require a different cycle.
- Determine the number of stretches in each monitoring unit that are to be sampled in a monitoring cycle, using the variance calculated from the baseline survey, or from similar watercourses, and the precision required (see boxes 4 and 5).

Box 4. Example of power analysis for two tributaries of the River Eden.

If we assume first that the between-stretch standard deviation remains high even with a decreasing population, then with 16 samples per monitoring round and a standard deviation of 3.4 (as in the two trial rivers), the probability of detecting a significant change between two sampling rounds of 1 unit (a difference of 1 crayfish per 10 refuges change in the mean abundance of crayfish in the monitoring unit from one monitoring cycle to the next) is only 0.08. For a change of 2 units it is only 0.22. (Note that there is no significant difference between the River Lowther and Scandal Beck, despite a difference of 2 between the means for these monitoring units). If the standard deviation decreases with the mean, however (which is to be expected), the power is higher.

Suppose the mean abundance recorded in Scandal Beck halved from 5 to 2.5 crayfish per 10 refuges, and the standard deviation between stretches also halved from 3.4 to 1.7. Then, again assuming no temporal correlation in the stretches, the probability of obtaining a significant change is increased to 0.44, assuming 16 sites are sampled (with one site per 500 m stretch).

If, on the other hand, the change is constant across all stretches, and there is some repeat sampling, the power increases enormously. For example, if 16 stretches are sampled in each round, 8 of which are repeat samples, and if the counts are exactly halved in these repeated stretches (while the other 8 stretches have random values from a distribution with a 50% lower mean), then the power is 0.95. With only 8 samples (half of them re-samples) it is 0.55.

In reality the power will probably be rather lower than this, but higher than the worst-case scenario outlined initially. Even in the worst case, it would still be possible to detect change in an entire river system (where presumably there will be several monitoring units or reaches, and therefore many more samples).

Box 5. Example of a monitoring study in Hampshire.

The crayfish population of the Candover Stream of the River Itchen in Hampshire has been surveyed for five years by Adrian Hutchings of Sparsholt College (Hutchings 2002). Ten sites on this 1.2 km length of chalk stream were surveyed annually from 1997–2001 using a 30-minute timed search.

There was considerable variation in the abundance of crayfish in different sampling sites. Some had several refuges in banks and a lot of large flints in the margins. The four sites with the best habitat for crayfish had counts ranging from 8–29, averaging 17.7 for all the samples. Two other sections were constructed around 1991. These engineered channels had little suitable habitat and few crayfish. Annual counts in the new section did not exceeded 4 in a section, and the average there was 1.3.

A two-way ANOVA showed that there were significant differences between sampling sites, but there was no significant difference in the average count for the reach from year to year. There was reasonable consistency over the five-year period according to habitat availability. The best sites had consistently greater abundance than those with little habitat. The average abundance for each of the 10 sites during the monitoring period was 9.6 crayfish per 30-minute search. Annual averages ranged from 8 to 11.9 during the five-year period. The population appeared to be stable during the period of monitoring, although Hutchings was concerned about the possible future effects of increased trampling by dairy cattle in one of the sections.

- Divide the total number of stretches to be monitored in two. Sample half of them in the first year of the monitoring cycle and half in the second or third year, to help average out the effects of climatic conditions and surveyor variation.
- In any one year of sampling during the monitoring cycle, select half of the sites from those

that were surveyed in the baseline survey (or the last monitoring cycle if the first one is completed) and select the other half as new sites, from randomly selected 500 m stretches. Eventually, all the stretches that can be surveyed will be included.

- There have been few long-term studies of abundance of crayfish and none using the standard method in this protocol. In addition to the monitoring cycle outlined above, a series of representative watercourses/monitoring units of different types is recommended to investigate variations over time. In a selection of watercourses there should be a programme of annual monitoring for at least five years, using a series of sampling sites in each monitoring unit. These watercourses should be chosen because they are characteristic of a type. The standard method should be used. However, for more intensive studies in selected monitoring units or reaches, it could be used in conjunction with other survey methods. This would provide a comparison of methods. Fixed-area sampling is often a useful addition, where conditions are suitable. Night-viewing and/or trapping may also be worth considering.

It is recommended that the monitoring strategy is reconsidered after the first cycle (after a baseline survey and one round of monitoring), when it will be possible to investigate the power of the strategy to detect change in a more meaningful way.

If there is only a small population, limited in extent in a catchment and the resources are available for monitoring, it may be possible to survey all stretches annually. Review this after five or six years. Either continue recording annually, or reduce to every three or six years if:

- The population is in favourable condition.
- Annual monitoring shows no declining trend in relative abundance.
- There are no known threats to the population.

Monitor any potential threats to the population annually, or as seems appropriate.

It is not necessary to use alternative methods of survey in a monitoring unit, unless the baseline survey or other preliminary investigation indicates that there are fewer 500 m stretches that can be sampled than for the required level of precision. Even then, it is preferable to use the standard method wherever practical. Given the lower power of methods such as trapping, it may be better to accept that abundance data from the standard method will be available from fewer stretches. Trapping may be of value, however, in confirming the presence of crayfish throughout the monitoring unit if there are extensive lengths that are completely unsuitable for manual survey. Used with care, trapping can also provide an indication of abundance.

6. Resources required

Once at a sampling site, the process of surveying and recording takes an average of 70 minutes. From parking, however, the time required to prepare, walk to a stretch, carry out the survey, return and pack up may be about two hours. Additional time is required to drive to the nearest point to a stretch. Two surveyors are likely to average three stretches a day, depending on the distances involved.

For comparison, fixed-area sampling takes about 30–45 minutes per 1 m^2 quadrat in stony streams, although time may be reduced or increased, depending on the amount of stone to be cleared. Hence, if five quadrats are recorded per site, this may take 2½–4 hours, around three times as long as the standard method.

Some additional travel time will be incurred when days are wholly or partly lost due to poor weather conditions and unsuitable flow in the rivers. This may easily add 10% to the time required for a survey programme. The effects will tend to be greatest on large rivers and in wet summers.

After the survey, data entry, checking, referencing photographs, etc., takes a further 0.75 to 2 hours per sampling site, depending on the number of crayfish recorded and the speed and accuracy of typing.

Surveyors should enter all data themselves, or at least check it to ensure no details are omitted.

Time required for analysis and reporting varies depending on the scale of the programme of work, but is likely to be several days per monitoring unit for a thorough survey report. It may be rather more if it includes analysis of external factors to produce a full report on the conservation status.

7. Key monitoring targets

For populations of white-clawed crayfish to have favourable condition they must have all of the following characteristics:

- Water quality at Environment Agency General Quality Assessment biological class A or B.
- Absence of crayfish plague.
- Absence of alien crayfish.
- Incidence of Thelohaniansis (porcelain disease) in not more than 10% of the population.

Additional details on these are given in Appendix 4.

There have been relatively few detailed studies of abundance of white-clawed crayfish in rivers, although several are in progress. Abundance of crayfish and other characteristics of populations are not included in the criteria for favourable condition at present. Given the present state of knowledge it is not possible to be conclusive about what would constitute favourable condition if abundance were included. Nonetheless, some guidance is given here, based on current knowledge. This should be reviewed and, where necessary, amended after a full monitoring cycle on a series of rivers. The following section suggests additional criteria and how these could be used to prompt management action.

- Juvenile crayfish <25mm carapace length should be present at all sites in the monitoring unit or reach where crayfish are recorded.
- Using the standard method, the proportion of juveniles (<25 mm carapace length) from a healthy population is likely to be about 40%. If less than 20% of the population is juvenile this may be due to lower efficiency of survey, or may indicate a problem with recruitment.

As yet, there is not enough information to be able to state what the relative abundance of crayfish is likely to be in rivers of different types. Table 6 sets out a grading scale, based on what is known. This should be reviewed after a monitoring cycle.

Table 6 can be used to grade sites and monitoring units on the basis of relative abundance of crayfish determined from standard surveys.

Table 6. Grading the abundance of crayfish – standard method.

Average no. per 10 refuges (at individual sites and average per monitoring unit)	Population abundance
>5	A: Very high
>=3, <=5	B: High
>=1, <3	C: Moderate
>0, <1	D: Low
0	E: Absent or undetected

From the field testing and comparison with rivers in other regions, it is clear that Scandal Beck, a tributary of the River Eden in Cumbria, is among the best streams for crayfish in the UK. Many of the sites have populations well in excess of the threshold for very high abundance and the grading for the stream as a whole is between high and very high abundance.

Not all sampled sites in a monitoring unit will have the same abundance, as this depends on the extent of favourable habitat for crayfish in individual stretches. Clearly, there will always be some sites that have abundance higher or lower than the average for the monitoring unit as a whole. Monitoring units of SSSIs and SACs that have been designated for white-clawed crayfish are likely to have populations with an average of moderate abundance or better, at least within the geographic range of the population in the monitoring unit.

There may be some rivers where the natural limitations of available habitat mean that crayfish never reach the relative abundances found in some of the Cumbrian rivers. Even populations with low abundance may be able to continue indefinitely, in the absence of major threats.

Fixed-area sampling, if it is used for any special studies, will normally be applicable only to individual sites. It is far too labour-intensive for whole reaches or monitoring units. There are only limited comparisons to date between the standard method and fixed-area sampling. Nonetheless, using published literature and unpublished studies for which fixed-area sampling is available, a tentative grading of abundance for individual sites is given in Table 7.

Table 7. Possible grading for abundance of crayfish – fixed-area sampling.

Average recorded density, no. of crayfish per m^2 (at individual sites only)	Qualitative assessment of relative abundance
5	**A: Very high**
2	**B: High**
0.2	**C: Moderate**
Present but <0.2	**D: Low**
0	E: Absent or undetected

Until at least one monitoring cycle has been completed on a series of rivers, it is difficult to set any definitive levels of change in population abundance that should prompt action. Any threats to the crayfish population will require management action (where it is possible to take action). Nonetheless, it is suggested that action may be needed if standard surveys show:

- Crayfish abundance at any sampling site falls by two grades.
- Average crayfish abundance in a monitoring unit falls by one grade.
- There is a significant reduction in crayfish abundance over three or more years in succession at annually monitored sites.
- The proportion of sampled sites occupied by crayfish in a monitoring unit or reach decreases by 10% or more.

If a reduction in abundance of crayfish is recorded, there should be an investigation to assess why this has occurred. Interpretation of the results will be aided by use of information on chemical and biological water quality, pollution risk, siltation and land use, and risk of transmission of crayfish plague.

- **Reduction in water quality**. Is this due to a pollution incident or diffuse pollution? Identify source if possible and encourage action to avoid further problems.
- **Reduction in substrate quality** due to excessive siltation. Assess current riparian land use and consider opportunities for enhancement.
- **Major change in river flow**. Analyse flow regime and assess whether change is due to natural climatic factors or other influences such as drainage regime, or abstraction from surface or ground waters.
- **Crayfish mortality**. Obtain samples for identification of disease. No action is possible to prevent mortality during an outbreak of crayfish plague, although natural recovery or reintroduction may be possible afterwards. Action should therefore be concentrated on preventing the spread of the disease to other waters. Not all cases of mass mortality are due to plague however, and the causes may be difficult to determine.

Increases in relative abundance of crayfish will tend to be due to favourable environmental conditions in a particular year, or underlying natural population cycles (currently unknown). It would be preferable to investigate significant increases in abundance as well as reduction to improve understanding of what promotes increase.

In some cases, increases may be due to positive measures to improve water quality, land use or channel habitat. Surveys should be carried out in advance of improvement measures being taken. Ideally, sample sites would be paired with others that have not undergone improvement measures. The trends in relative abundance in the treated and untreated lengths of river would need to be compared over several years.

References

Armitage V (2000). Observations of radio-tracked crayfish (*Austropotamobius pallipes*) in a northern British River. In: Rogers D & Brickland J. *Proceedings of Leeds Crayfish Conference, April 26–27, 2000*, Environment Agency, Bristol.

Boon PJ, Holmes NTH, Maitland PS & Rowell TA (1996). *SERCON: System for Evaluating Rivers for Conservation. Version 1 Manual.* Scottish Natural Heritage Research Survey and Monitoring Report No. 61, Scottish Natural Heritage, Edinburgh.

Cowx I & Harvey J (2003). *Monitoring the Bullhead*, Cottus gobio. Conserving Natura 2000 Rivers Monitoring Series No. 4. English Nature, Peterborough.

Foster J (1993). The relationship between refuge size and body size in the crayfish *Austropotamobius pallipes* (Lereboullet). *Freshwater Crayfish* 9, 345–349.

Environment Agency (1999). *Freshwater Crayfish in Britain and Ireland*. Environment Agency, Bristol.

Holdich D (2003) *Ecology of the White-clawed Crayfish*, Austropotamobius pallipes. Conserving Natura 2000 Rivers Ecology Series No. 1. English Nature, Peterborough.

National Rivers Authority (1992). *River Corridor Surveys, methods and procedures*. Conservation Technical Handbook No. 1. National Rivers Authority, Bristol.

Peay S (2000). *Guidance on Works Affecting White-clawed Crayfish*. English Nature and Environment Agency Contract FIN/CON/139, English Nature, Peterborough.

Peay S (2003a). *Monitoring the White-clawed Crayfish: Field-testing in River Eden Tributaries*. Unpublished report for English Nature, Peterborough.

Peay S (2003b). *Guidance on habitat for white-clawed crayfish and how to restore it*. R&D Technical Report W1-067/TR. Environment Agency, Bristol. 66 pp.

Peay S & Rogers WD (1999). The peristaltic spread of signal crayfish (*Pacifastacus leniusculus*) in the River Wharfe, Yorkshire, England. *Freshwater Crayfish* 12, 665–676.

Robinson CA, Thom T, Lucas MC (2000). Ranging behaviour of a large freshwater invertebrate *Austropotamobius pallipes*. *Freshwater Biology* 44, 509–521.

Kemp E, Birkinshaw N, Peay S & Hiley PD (2003). *Reintroducing the White-clawed Crayfish, Austropotamobius pallipes*. Conserving Natura 2000 Rivers Conservation Techniques Series No. 1, English Nature, Peterborough

Sibley P (2000). Signal crayfish management in the River Wreake catchment. In: Rogers D & Brickland J. *Proceedings of Leeds Crayfish Conference, April 26–27, 2000*, Environment Agency, Bristol.

Sibley P J, Brickland JH, Bywater JA (2002). Monitoring the distribution of Crayfish in England and Wales. *Bull. Fr. Pêche Piscic.* 367, 4, 833–844.

JNCC (1998). A Statement on Common Standards for Monitoring Designated Sites. Joint Nature Conservation Committee, Peterborough.

Appendix 1. Survey forms and instructions

(Note: all forms and instructions can be downloaded from www.riverlife.org.uk/species/crayfish.html)

Crayfish record card

Catchment			River			Site reference		
Date			**Surveyors**			**Sheet no.**		

Record no.	Species	Sex	CL (mm)	Damage	Disease	Breeding	Moult	Sub-site location ref.	Catch method
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									

Additional comments:

Crayfish habitat survey card

Catchment		**River**	**Site** (no., name)
Date (dd/mm/yy)		**Surveyors**	**Grid ref.** (d/s end)
Weather, good 1,	**Flow norm 1, low 2, mod. 2, poor 3**	**Water temp.** (°C) **fall 3, rise 4**	**Clarity, good 1, mod. 2, poor 3**
Photo ref. & location	**Width channel** (m)	**Start/finish time**	
Site length (m)	**Description** (channel features, land use)		

Sample	**Patch 1**	**Patch 2**	**Patch 3**	**Patch 4**	**Patch 5**
Survey method, std 1, quad 2, net/kick 3, trap 4, view 5					
Details (if not standard)					
Extent (l x w patch)					
Channel (1 margins, 2 mid, 3 both, other specify)					
Depth (metres)					
Feature (1 marg. d'water, 2 pool, 3 glide, 4 run, 5 riffle)					
Refuges in channel (tick all present in patch, ring main type(s) searched)					
Cobble (6.5–15cm)					
Cobble (15–25.6 cm)					
Boulder (25.6-40 cm)					
Boulder (>40cm)					
Rubble (give size)					
Woody debris					
Other urban debris					
Tree roots, fine					
Moss					
Filamentous algae					
Other submerged vegetation					
Emergents					
Main substrate beneath					
Bedrock					
Cobble (6.5-15 cm)					
Pebble (<6.5 cm)					
Gravel (<1.6cm)					
Sand (<2mm)					
Clay					
Silt					
Siltation					
None					
Low					
Moderate					
High					
Refuges in bank					
None					
Cobble/boulder					
Tree roots, large					
Vertical or undercut bank					
Dry stone wall					
Other reinforced					
Crayfish burrows					

	Patch 1	Patch 2	Patch 3	Patch 4	Patch 5
Shading above					
Crayfish from 10 refuges Search time					
Bullhead present?					
Evaluation crayfish habitat for whole site (0 none, 1 pres., 2 freq., 3 abund.) **In margins**	**Score**	**Notes** (survey conditions, patches, etc.)			
In mid-channel					
In banks					
Surveyability					
Problems pollution 1, erosion 2, (E if >33% affected), aliens 3.					
Total crayfish (by 1 method, note total(s) by other methods in notes if applicable)					

Crayfish record card instructions

REFERENCES	Catchment, river, site reference, date and surveyor are as on habitat record. Site ref. and date must always be included **to ensure records are correctly attributed.**
SHEET NO.	(e.g. use 1 of 2 if you have more than 45 crayfish recorded at this sampling site)
	SPECIES
A	*Austropotamobius pallipes*, **white-clawed** crayfish
P	*Pacifastacus leniusculus*, **signal** crayfish
T	*Astacus leptodactylus*, Turkish or **narrow-clawed** crayfish
N	*Astacus astacus*, **noble** crayfish
R	*Procambarus clarkii*, **red swamp** crayfish
S	*Orconectes limosus*, **spiny-cheeked** crayfish
U	**Unconfirmed** (can be used temporarily until identification of alien species is checked)
	SEX
F	**Female**
M	**Male**
N	**Juvenile** (0+ not distinguishable)
X	**Escaped crayfish**, not identified
	CARAPACE LENGTH (CL)
	Carapace length, to nearest mm, from tip of rostrum to junction of carapace and tail. Do not use total length (i.e. head to end of tail).
J	**Juvenile**, **escaped**, estimated size <25 mm CL (you have the option of estimating size in more detail – e.g. J c.10–15mm)
A	**Adult**, **escaped**, estimated size >25 mm CL, (have option to estimate size in more detail)
	DAMAGE record injuries (optional; damage need not be recorded)
MR	**Missing right** cheliped (large front claw)
ML	**Missing left** cheliped
MB	**Missing both** chelipeds
RR	**Regenerating right** cheliped (noticably smaller than other one)
RL	**Regenerating left** cheliped
RB	**Regenerating both** (both chelipeds noticably small for the size of crayfish
AR	**Antenna damaged** or missing, right side
AL	**Antenna damaged** or missing, left side
OM	One or more **other** limbs **missing** or damaged
OI	**Other injury**, e.g. cracked shell (sign of attack by predator, such as heron, or rarely damage during manual survey)
Z	**Dead crayfish** (note if porcelain disease or plague in next section, otherwise add note in additional comments on cause of death if known). **NOTE: crayfish may have died outside survey area, so keep separate from other results**.
	DISEASE
PD	**Porcelain disease**, Thelohaniasis. Underside of tail is opaque white, instead of translucent. **Always record this**.
BS	**Burnspot disease**, discoloured patch(es) on exoskeleton, usually dark brown or black in centre and reddish at rim. Looks like rust. Exoskeleton may be perforated. More likely if crayfish is injured.
CW	**Crayfish worms**, Branchiobdellans. Attached to surface of crayfish, usually 1 mm to a few mm long, white or off-white colour, not parasitic.
CP	**Crayfish plague**, *Aphanomyces astaci* – see notes. Abnormal behaviour, stiffness in joints, dark patches at junction of legs and tail. **WARNING: take immediate action if suspected and disinfect all gear.**
	MOULT
	Intermoult, need not be recorded
BM	**Pre-moult** (before moult), crayfish usually dark and has noticable separation of epidermis from exoskeleton, carapace deforms easily

MM	Moult, (**mid-moult**) crayfish feels soft, like gelatin. Only lasts a few hours.
AM	Post-moult (**after moult**). Light, clean appearance. Post-orbital ridge and cervical groove easily bent. Carapace often feels leathery.
	BREEDING CONDITION
B	**Berried female**, carrying eggs.
Y	**Female carrying young. WARNING! Handle with care**, as tail flicking may lead to loss of young. Keep tailed tucked around young and minimise handling.
GS	Female has old **glair strands**, former attachments for eggs, look like thick brown threads. If in summer, indicates has bred, if in winter or spring means was infertile or lost eggs.
G	Female has new **glair** forming, whitish secretions at the edges of the tail sections, in autumn only, indicates coming in to breeding condition.
S	Female has **spermatophore** attached, white mass, only immediately after mating in autumn, rarely seen.
	SUBSITE LOCATION REF.
	Optional, can be used to indicate position of crayfish within a sampling site, e.g. in which patch found (P3, P4 etc.). Could also be used in conjunction with habitat codes if required, or other references.
	CATCH METHOD
	NOTE: **catches by different methods should be recorded here and totalled separately, NOT aggregated for the sampling site.**
1	Manual, **selective search of refuges** (i.e. recommended method, or a selective timed search if used)
2	Manual, **by quadrat** other fixed area; full systematic search of refuges in a defined area of bed.
3	**Netted** in vegetation or other refuges, by sweep-netting or kick-search
4A	**Trap, baited**, any type
4B	**Trap, unbaited**, any type, offers refuge
5	**Night-view** (survey by torchlight)
6	**Electrofishing** (usually as incidental records during fisheries survey)
	ADDITIONAL COMMENTS
	Can be used to note, for example, cause of crayfish death if known; evidence for crayfish presence, e.g. '2 moulted carapaces found' at a site with few or no crayfish recorded; more details on location, e.g. 'P4 breeding females all found under large boulders beneath low canopy'; observations of behaviour, e.g. 'crayfish 7 seen feeding on moss', 'nos. 2 and 3 seen in threat display', '7 crayfish under 2 adjacent refuges, may be feeding on dead crayfish', etc.
Extra	If doing capture-mark-recapture study, have an option to either replace record no. or location reference with mark details, or add a column to the right

Crayfish survey and habitat card instructions

Catchment	name	As defined by Environment Agency or other relevant statutory agency.
River	name	As on maps or as defined by statutory agency.
Site	reference	Can include number/code, plus a name/description.
Date	dd/mm/yy	Day, month, year.
Surveyors	name(s)	**Two or more surveyors recommended for safety.**
Grid ref.	OS grid ref	At downstream end, unless otherwise noted; 10 figure, to about 10 m (e.g. NY 7274 0715).
Weather	1 good	Dry, fairly bright, not windy.
	2 mod.	Dry, overcast, may have some drizzle or wind.
	3 poor	Rain and/or wind, **should avoid survey in these conditions.**
Flow	1 normal	No obviously high or low flow conditions.
	2 low	Parts of banks and bed exposed, reduced width of wetted channel in many areas, may be shallow pools left.
	3 falling	Flow conditions are adequate for survey, but flow is reducing after high flow, may have had some rain in past 2 days.
	4 rising	**Do not survey in high or increasing flow.** Record this if conditions were suitable initially, but have any increase in velocity, onset of foam flecks or any rise in level during survey – **recommend end survey now** – safety risk and deteriorating conditions for survey.
Water temp.	degrees C	Affects catch efficiency. Cold conditions, crayfish are deeper in bed, but sluggish so juveniles easier to catch. High temperature, more crayfish active on bed, escape swims very fast – net only. **Always record this for trapping or night-viewing**.
Clarity	good	Water clear, visibility to bed good to 50 cm depth.
	moderate	Water largely clear, though may be some suspended solids. Visibility reasonably good to 30cm, but may be more difficult to see clearly at 30–60 cm. Or may have to wait longer than usual for bed to clear. Or water is clear, but coloured (e.g. peat-staining) – note this.
	poor	High degree of turbidity/suspended solids, sufficient to make manual searching difficult. Will affect survey efficiency and may need to use other methods, netting, set traps.
Start finish	hh:mm	Arrival time at site, at start of session and departure time; option to record time to walk to site in Notes.
Photo ref.	no./ code	No. or other reference, normally at least 1 general photo, optional extras for features. Can detail up to 10 on form. Location: OS grid ref., or brief description (e.g. view u/s from d/s end; refuges in P3).
Site length		Total site length, normally 100 m; may be 200 m for large rivers. May be less than 100 m for intensive fixed-area surveys.
Width		Approximate width in metres, or can give range.
Description		Overall features of the channel, (e.g. proportion/location of glides, riffles); type of banks (e.g. if banks steep, undercut, left bank gently sloping, fringe of emergent vegetation, etc.), land use (e.g. woodland, adjacent pasture, fenced or not).
Survey method		Standard method (1). If other methods used, show in which patches. **Never aggregate number of crayfish caught by different methods**.
	1 standard	Selective search of refuges, 10 in each of 5 patches generally. If do more patches continue on a 2nd sheet.
	2 quadrat	Complete search of all possible refuges in a small, defined area, may be fully enclosed or open (state which).
	3 net/kick	Selective sweep-netting or kick-sampling
	4 trap	Crayfish trap
	5 view	Night view, in clear water at night with a torch.
	6 other	Electrofishing, scuba, etc., give details

Details	Describe	If trap, state type used; (e.g. pyramid trap, 2 mm mesh, straight-sided top entry; Swedish trappy, extra 1 mm mesh wrapping; refuge trap, 8 no. 30 mm tubes). If quadrat give dimensions and whether enclosed or not. Use space in notes section if required.
Extent	metres	Give approximate dimensions of each sample patch, may be as little as $1m^2$, or up to 10 m length of channel. (l is distance u/s, w is distance at right angles to bank), typically $1–10m^2$ in stony streams.
Channel	1 margin, 2 mid, 3 both	Margin, not more than a quarter of channel from left or right bank, or as distinguished by a change in flow type (e.g. mid-channel riffle or run may have glide or marginal deadwater in shallow margins); usually within 1–2 m of bank.
Depth	metres	Average in habitat patch surveyed, or can give range.
Feature		Terms as in RHS. Can also record if canal, A; pond <0.1ha, B; pond/lake >0.1 ha, C. Can add E to 1 or 3 to indicate that this margin is next to higher-energy flow.
	1	Marginal deadwater; in margin, no discernible flow, or only slight upstream eddy
	2	Pool; no obvious flow, deep water, extends across most of width of channel.
	3	Glide; visible flow, but no waves or surface disturbance, except possible ripples around exposed rocks.
	4	Run; faster than a glide, surface has rippled surface, but little turbulence, may get a few small waves around stones, but minimal. Typically upstream of a riffle, or where channel narrows and speeds flow.
	5	Riffle; shallow fast-flowing water with a disturbed surface and mainly unbroken standing waves on the surface, a feature with relatively high energy of flow. (Don't record as riffle if just due to submerged plants).
	6	Rapid, has whitewater broken standing waves, normally over cobble, boulder or bedrock, with a steep gradient; high energy (seldom suitable for crayfish or survey or both). (Traditionally might have been classed as steep riffle).
Refuges		Tick all refuges in the channel present in the habitat patch. Ring main type(s) searched.
	Cobble	Large cobble 15–25 cm is preferred, especially in high/moderate energy watercourses. Small cobble 6–15 cm will be used only by small crayfish, if at all.
	Boulder	Do not haul out deeply bedded boulders. Safety – be careful handling large stones.
	Rubble	Any loose construction materials, 15 cm and larger, e.g. concrete or brick. Give typical size of material.
	Woody debris	Trees, logs, branches and other flood debris in the channel.
	Other urban debris	Anything manmade offering a potential refuge, (e.g. old tyre, traffic cone, large can, supermarket trolley full of leaf litter, etc.).
	Tree roots, fine	Underwater tree roots; fine, matted, e.g. alder. (Note: large roots in banks are in Bank features).
	Moss	Record only if extensive enough to provide a refuge,(e.g. abundant swathes of *Fontinalis*).
	Filamentous algae	Record only if extensive, e.g. on trailing from rocks or in patches on bed (ignore minor fuzz on rocks, but make comment in notes if this affects visibility or may indicate a problem).
	Other submerged	Submerged vegetation, any other type, (*Ranunculus* spp., *Callitriche* spp., *Potamogeton* spp., etc.), if sufficiently dense to provide a refuge.
	Emergents	Rooted emergents, (e.g. *Rorippa*, *Phragmites*, *Carex*, *Petasites*, etc.).
Main substrate beneath	Standard types	Cobble 6.5–15 cm, pebble<6.5 cm, gravel <1.6 cm, sand <2 mm, clay, sticky, solid surface, silt 'silky' deposited. Search efficiency will be poor if cobble layer present beneath, also lower if bed is silt or clay. **Search everything, down to fine material or solid bed if possible – crayfish may be under small cobble/pebble under a boulder**.

Siltation	none	None. Organic material if present is coarse leaf litter, no accumulation of silt on surfaces.
	low	A little silt trapped in moss/algae on stones; refuges clear, e.g. only some leaf litter, or clearing before crayfish can wander off.
	moderate	Usually abundant algae on stones or bed, with silt or other fines clouding water when moved, but clearing slowly. May be a little silt below stones. Need to wait longer to view under refuge, but can still see crayfish if present.
	high	Silt cover on all surfaces and some in refuges. May be a soft suspended layer just above bed in dead water, very slow to clear and may not settle sufficiently for effective survey (crayfish wander off). If lots of suspended silt present, probably unsuitable for crayfish. (If dead water too silty may need to survey in glides or faster water only).
Refuges in bank		Potential refuges, submerged or usually so at normal flow, with crevices for crayfish – in/adjacent to the sample patch. Omit this if the patch is mid-channel only.
	none	None evident, e.g. shallow sloping bank, poached, active erosion, inaccessible reinforcement.
	cobble/ boulder	In margins and projecting from bank in water.
	tree roots, large	Usually associated with undercut banks, projecting roots often forearm thick or more.
	vertical or undercut bank	Will usually be relatively stable, tend not to have collapsed toe, or if so it is normally submerged. Vertical banks may be bare or have some vegetation. Slightly undercut below water, with overhanging vegetation is favourable.
	dry stone wall	Bank reinforced with unmortared stone.
	other reinforced	If suitable, providing submerged crevices for crayfish. Less likely to be suitable if there is adjacent fast flow. Describe in notes.
	crayfish burrows	Holes in earth banks, usually submerged, but may be exposed during low flows. White-clawed burrows usually 2–6 cm wide, smaller than rat or water vole holes. Characteristically wider than high, though old ones may be eroded more. Burrows often hidden in undercut banks under vegetation. Signal crayfish burrows often larger, also deeper and more extensive. Note if signals causing slumping of banks.
Shading above		Any type of canopy cover from trees or shrubs (>33% of this habitat patch with canopy above).
Crayfish		Record no. crayfish caught in 10 refuges, plus escapes if reasonably sure not caught subsequently (or total for sampling unit, e.g. fixed-area, trap etc.).
Search time		Record time spent searching, excluding survey notes and processing catch
Bullhead present?		**Optional**. May want to record bullhead, which use same habitat at crayfish. Could note presence, or do count per 10 refuges.
Evaluation of crayfish habitat for whole site	Abundance	Score separately for **margins** (area with visibly different flow to mid-channel, or up code to 1/4 channel width both sides), **mid-channel** (consider stream energy and consolidation, mid-channel stone may be too bedded to provide refuges) and **banks** (optionally, can score separately for now/summer – N, and normal winter conditions – W).
	0	**Not evident, or only minimal potential for refuges.**
	1	**Present, but localised or sparse, in less than a third of site.**
	2	**Frequent, covering more than a third of site, or frequent, but small patches.**
	3	**Abundant. Potential refuge habitat continuous, or semi-continuous, along more than two-thirds sample site.**
	?	Can use/include query if not sure of evaluation, (e.g. cannot see well or probe)

Surveyability	**0**	**Either cannot access for manual survey, or fewer than 10 searchable refuges.**
	1	**Difficult finding sufficient patches, 2 or more considered only moderate or poor potential; or searched more than two thirds accessible refuges.**
	2	**Likely 1 to 5 more patches worth surveying, could extend surveyed patches.**
	3	**Could survey at least 5 more patches similar/equivalent.**
Problems		1: signs of pollution, (e.g. septic tank discharge, slurry, etc.). 2: poaching, heavy trampling of banks and stream with bare ground, erosion. Add E if extensive part (>33%) of sample site affected. **If pollution present inform relevant agency**. Give details. 3: Aliens. Will record separately, but flag here, too.
Notes		Additional notes on features, or survey. Detail any limitations of the survey (e.g. surveyed from right bank only; too deep in 70 m length; peat staining, reduced visibility in water over 0.3 m). Include notes on patches or other relevant observations (e.g. abundant moss litter under boulders in P2 and P3; otter spraint on mid-channel boulder, eels in patches 1–3; P2 shallow dead water next to riffle, looked unpromising, but frequent juveniles under exposed mossy boulders, P4 deep cobble/pebble under boulders, reduced efficiency, etc.) Continue on separate sheet if required, ensure have site ref. and date.

Appendix 2. Precautions against crayfish plague

Disease precautions are essential to prevent the spread of crayfish plague (*Aphanomyces astaci*), which produces free-swimming zoospores that are specific to crayfish and can be carried in water and mud, and on damp equipment. The risk of picking up spores is greatest at times of a plague outbreak, when the number of zoospores is high.

As the spores remain viable only when damp, complete drying of equipment that has been in contact with water or sediments is an effective way of killing them. Washing mud off waders on site, preferably with a scrubbing brush, will also reduce the risk of transferring spores elsewhere. Clean mud from equipment prior to disinfecting or drying. Spores can also be killed by disinfectants. A hypochlorite solution can be used, such as domestic bleach, or an Iodophore-type disinfectant at 100 ppm available iodine for at least five minutes. If equipment cannot be dried, it must at least be cleaned thoroughly to avoid transfer. Disinfectants can be applied using a spray applicator, although it may be necessary to use a bowl to dip nets and other equipment.

All sites known to support native crayfish should be sampled with clean and dry equipment. A second set of clean equipment could be carried in the vehicle and used when appropriate. All equipment used at sites known to contain signal crayfish must be cleaned and dried out thoroughly before it is used at other sites.

These procedures should be emphasised to any person or organisation that may potentially transfer the plague.

If you suspect a plague outbreak, because dead crayfish are found or individuals show abnormal behavioural signs, specimens should be sent for diagnosis. It is essential to telephone in advance. There is no charge for this service.

Send specimens immediately to:

Dr David Alderman
CEFAS
Barrack Road
The Nothe
Weymouth
Dorset DT4 8UB
Tel. +44 (0)1305 206600

In addition specimens can be sent to:

Dr David Rogers
Crayfish Consultants International Ltd.
9 The Moat
Castle Donnington
Derby DE74 2 PD
Tel. and fax +44 (0)1332 850156

For both the above, moribund or very recently dead specimens should be sent via a courier in a cool box with ice packs, and kept damp. Moribund specimens are preferred, because the growth of other fungi and bacteria after death soon masks the crayfish plague fungus. Diagnosis was formerly a slow process involving culture of the crayfish plague fungus. A much more rapid diagnosis can now be made using the polymerase chain reaction. Crayfish preserved in 80–90% ethanol can be used for this method.

Appendix 3. Additional notes for surveyors

The following notes provide some additional guidance for surveyors and may be used as an aid during training. They are not a substitute for training, and practice in the field with an experienced surveyor. The notes should be read in conjunction with the monitoring protocol and the instructions for completing the recording forms.

A3.1 Searching for crayfish

Within the sample site, decide on five patches of habitat to be surveyed. Select the most favourable-looking patches within a sampling site, those that offer the best potential refuges. It is not necessary for these to be evenly distributed along the length of the site. Indeed, the pattern of riffles and pools in many rivers means that it is quite likely that patches will be clustered in particular features within the site. For example, there might be two slow-flowing lengths of glide with abundant boulders that total, say, 50 m of a 100 m site.

Aim to search 10 refuges per patch. A patch might be as little as 1 m^2, or up to 10 m length of watercourse. In general, patches should be at least 5 m apart.

In some watercourses there may fewer than 10 items per patch that are worth surveying. Keep note of the number of potential refuges searched and move on to additional patches in the survey site.

If soon after starting at a chosen patch you find it to be much less suitable than it appeared, either for refuges or for manual survey, you can leave it and select another patch if there are others that are obviously better. For example, an area of marginal deadwater may have so little movement of water that silt will not clear. Changing choice of patches should not be used as a way of discounting patches that appear to be suitable, but happen not to have crayfish when surveyed.

Large stones are preferable and favoured by crayfish because they are usually more stable than small stones. Other refuges, such as logs, bits of concrete or old tyres, also offer potential refuges and may be more prevalent in some lowland rivers.

The essential characteristics of a refuge are that it is:

- Large enough to cover the crayfish.
- Relatively stable (resistant to high flows).
- Not in so strong a current that it is difficult for a crayfish to walk out of the refuge not too silted.

Work facing upstream to minimise disturbance of soft substrate. Preferably lift or turn each stone in a downstream direction, for the same reason. Allow the bed to clear beneath the stone, but hold a net in any rush of water that occurs when the stone is lifted, in case a crayfish is washed free. Be patient until the bed is visible.

If there are other stones beneath a boulder or large cobble, lift these too, counting all as a single refuge. Any crayfish will usually be on the gravel, sand or other soft substrate beneath the stones. Check the pebbles under cobbles or boulders – there may be crayfish burrows underneath. Always work down to the base substrate.

If the bed is covered in deep cobble with several stones in a layer, survey efficiency will be greatly reduced. Crayfish may be present, but they tend to creep into the interstices between the stones before they can be seen and even if seen are difficult to capture. Search stone that is mainly a single layer on a small-grained substrate whenever possible.

Where practicable, replace refuges after searching them, putting them back vegetated side up to minimise disturbance to other organisms. In sites with an abundance of suitable refuges, displacement of some stones is not likely to affect the crayfish. In some upland streams, however, the patches that have good habitat may be very localised and small. Moving boulders from an area of marginal deadwater into fast-flowing water nearer the mid-channel could reduce the suitability of the patch for crayfish in such streams.

Visibility is reduced if wind or rain ripples the water surface. Avoid surveying in these conditions, and never survey during increasing flow. During low light conditions in the shade of trees a waterproof torch may be helpful.

A viewing-aid provides much better visibility in rippled flow and in bright sunshine. Survey efficiency is reduced without a viewing aid. A wooden drawer with a clear plastic bottom and a string attached to the handle is recommended as the best viewing aid. Here is a description of how the equipment could be used.

- Wet the clear base of the drawer with water, just enough to cover the bottom.
- Find a suitable-looking refuge to search.
- Move the drawer upstream or to the side of the selected refuge.
- Turn or lift the refuge.
- Pull the drawer over the exposed area and watch as any disturbed sediment clears.
- If using a hand-held net, put this in the outflow of sediment immediately after moving the stone, to catch any crayfish that are washed out.
- Keep the search-images in mind – for crayfish walking; sitting with tail tucked under and claws in; individual claws and antennae. Be alert for juveniles as well as adults.
- In general, a crayfish will stay where it is for a time before starting to walk forwards or backwards towards a new refuge.
- When a crayfish is visible, decide on the best approach for catching it – the best method is a cautious approach from above and behind, then a sudden grab for the carapace, pressing the crayfish down on to the bed, gently but firmly, until a good hold is obtained and it can be lifted out of the water.
- Juveniles take more skill to catch. If necessary, position a hand-held net downstream in a clear area about 10 cm from the crayfish, or nearer if possible without alarming it. At the same time, bring a finger slowly towards the front of the crayfish, to encourage it to back away, but not escape-swim. Hold the net so it offers a potential refuge – black or green mesh is best.
- Once the crayfish enters the net, scoop it up quickly. If a crayfish escape-swims into a net, lift it up immediately, or it may bounce off the back and escape.
- Look carefully at the exposed area after catching a crayfish – there may be others, including those emerging from concealed refuges. Carefully remove any cobbles or pebbles under the primary refuge. Stay alert for signs of crayfish or their burrows.
- If something disappears at high speed the moment a stone is moved, it is usually a fish. Never record an escaped crayfish unless you positively identify it as a crayfish.
- A crayfish does an escape-swim by making a strong thrust of its tail and shooting off backwards, sometimes at an angle to the direction it was moving in. It is most unlikely to be caught by hand, although it may be caught in a net, if it happens to be in the right place to intercept the crayfish. Watch to see where the animal settles if possible. If it is nearby and in the direction of working, it may be possible to catch it manually. It is likely to be prone to swim again.
- Juvenile crayfish are difficult to catch, especially the young of year, 0+ crayfish. Use a hand net as necessary and expect some escapes.
- When the refuge has been fully searched, put the crayfish back, where practical, especially if favourable habitat is limited – throw a few pebbles back under the boulder to keep a void open so crayfish can use it again.

If there are two or more crayfish under one stone, it takes some skill and a little luck to capture them all. If you can make an easy and rapid catch of the larger one without disturbing the smaller one(s) do so. However, the large animals tend to sit still for longer after a refuge is removed and are easier to see if they start to wander off to a new refuge, so going for smaller crayfish first is often the best strategy. If additional small juveniles are present, note their presence and try to catch them if feasible, but expect lower catch efficiency.

Multiple occupancy of refuges leads to more escapes. Losses of 30% are common, even with experienced surveyors. Avoid double-counting. Remove the escape from the count if you know which refuge it has moved to and catch it subsequently. In general, do not waste time chasing escapes. If a crayfish makes an escape swim it is more likely to do so again if pursued. Keep a mental or written tally of escapes during the search of 10 refuges in a patch. Do not be tempted to search a refuge just because there may be a recent escape under it – choose the most favourable-looking refuges.

Groups of crayfish tend to moult synchronously, and may be harder to find if surveying during a moulting period. They spread out and may use sub-optimal refuges during this vulnerable period. It is difficult to predict when moulting will occur and different sexes and age groups may moult out of phase anyway. This is a limitation that cannot be avoided, but the effects can be minimised by dividing monitoring effort between different occasions.

A3.2 Processing the catch

As each crayfish is caught in a habitat patch, hold it temporarily, either in the viewing-aid, if using a clear-bottomed drawer, or in a small bucket or similar container. A clean plastic paint-tub can be used, or other household container. A useful design is a plastic container that has two compartments side by side and a central handle (of the type often used for holding shoe-brushes), because crayfish can be put in one side and then moved to the other once recorded. Put some clean river water in the bottom of the container, although crayfish do not necessarily have to be fully immersed. Crayfish prefer to have something to hide under. They settle down readily if provide with a handful of aquatic vegetation, or a piece of fabric, such as a net or even just a clean kitchen cloth.

After surveying a patch, record its habitat features using the crayfish survey and habitat record sheet. There is an instruction sheet with the form. Record the catch of crayfish on the crayfish record card (see Appendix 1 for forms and further instructions on recording). This will usually be copied onto the reverse of the habitat record sheet.

Return the native crayfish to refuges in the habitat patch from which they came. Check that all necessary records for the patch have been completed and move on to the next patch.

Individual surveyors can work different patches nearby, or work jointly in one patch. If surveyors are working patches separately from each other, extra buckets and recording equipment may be needed. It is preferable to record a site on a single sheet, but results can be combined if necessary.

Avoid handling a berried female close to the time of release of the young, as the hatchlings may be shed and lost.

Young are usually released in late June in southern England, but this can occur as early as late May, or be delayed due to a late, cold spring. In Cumbria and Northumberland crayfish tend to release their broods in July and there may be some females with young up to the end of July or even early August.

Hold any female that is found to be berried or carrying young carefully, keeping the tail tucked underneath to minimise the chances of a tail-flick detaching eggs or young. Do not drop any female with eggs or young into water; release it carefully, preferably directly into the entrance of a potential refuge. If hatchlings are accidentally shed, release them into favourable habitat in the margins.

A3.3 Notes on disease

Thelohania contejeani, a protozoan that causes porcelain disease (Thelohaniasis), may be present in up to 10% of a population without apparent harm, although rates of 0.1–3% are more usual. Problems may occur if a higher prevalence is reached, as female crayfish with advanced Thelohaniasis do not breed. Infected individuals have porcelain-white coloration to the tissues (particularly the tail muscles) when viewed from the underside. Porcelain disease should not be confused with secretion from glair glands. Glair secretion gives a similar coloration to the crescent-shaped ridges at the lateral margins of the underside of the tail in females coming into breeding condition in autumn (see inside back cover for colour illustrations, and Holdich 2003).

Burnspot disease can be caused by several types of fungi and bacteria. The symptoms are a patch of discoloured cuticle, usually dark brown or black in the centre and reddish towards the rim, an appearance like a spot of rust. The cuticle may be perforated. The disease is more likely if crayfish are injured, for example after a failed attack by a heron, or after losing a limb.

'Crayfish worms' are occasionally found attached to crayfish and are most likely to be seen during moulting. They are *Branchiobdella*, a species of annelid worm. They are usually a few millimetres in length and tend to live not as parasites, but simply attached to the surface of the crayfish.

Crayfish plague, an oomycete fungus (*Aphanomyces astaci*), is carried by North American crayfish, such as the signal crayfish. It is lethal to the white-clawed crayfish and causes mass mortalities. The fungus is very difficult to see with the naked eye. Its effect can be seen in behavioural abnormalities and in the melanisation of leg and tail joints (brown patches on the membranes between the joints). Crayfish may be seen out during the day and may have an irregular, stiff-legged walk. Limbs may easily become detached.

The dark patches between the joints should not be confused with brown spots characteristic of bacteria causing burnspot disease.

A white mass on the underside of females in the autumn is not the fungus but the spermatophore attached during mating. The fungus is rapidly masked after the death of a crayfish by the colonisation of other fungi, such as *Saprolegnia* species. The best diagnosis of the disease is therefore from moribund crayfish, rather than dead ones.

Mass mortality in white-clawed crayfish is not necessarily due to crayfish plague. Pollution incidents may be responsible. Large floods can cause mass deaths and stranding on the floodplain. Some dead crayfish are often found during moulting periods as a proportion of individuals fail to complete the moulting process properly. There may also be other reasons why many deaths occur, perhaps related to natural cycles in populations.

A3.4 What to do with alien crayfish

The UK Wildlife and Countryside Act makes it unlawful to release any alien crayfish into the wild. In principle, therefore, if a surveyor finds any alien crayfish they should not be returned to the river after the survey. Once alien crayfish are established in a watercourse, and at an abundance that can be detected in surveys, it is not possible to eradicate them with any known and accepted method. Hence removal of a few alien crayfish found during in a survey will do nothing to improve the prospects of any native crayfish population in the area.

The method recommended by the Environment Agency for killing crayfish as humanely as possible is to place them in a container in a freezer. This leads to torpor and death. If this approach is adopted, it is essential to have a secure method of transporting alien crayfish for appropriate disposal, without any risk of them escaping elsewhere. This movement of crayfish would require prior approval. The issue should be discussed with the relevant statutory agency. If in any doubt about the security of moving alien crayfish to a place for disposal, the safest option is to put them back where found.

Appendix 4. Determining favourable condition – some additional notes

Any action plan for the conservation of white-clawed crayfish needs to operate at the catchment level rather than solely the SAC boundaries. SAC designation does not necessarily cover the whole river system and problems outside SAC could lead to reduction or loss of favourable condition for white-clawed crayfish within the SAC.

There are four main potential threats to white-clawed crayfish. These may not be fully addressed in the specific crayfish surveys in the protocol, but information on these threats should be included in the assessment of whether a population is in favourable condition. Information on threats to white-clawed crayfish will help in the interpretation of the results of the baseline and monitoring surveys undertaken.

The main issues are:

- Presence of alien crayfish
- Risk of crayfish plague
- Risk of pollution
- Land use, erosion and siltation.

A4.1 Presence of alien crayfish

The presence of alien crayfish in a catchment is usually the greatest threat to a population of white-clawed crayfish.

For monitoring condition of white-clawed crayfish record:

- Alien species in catchment – distance to known population by water if known to be present.
- Alien species nearest known population, direct distance overland (km).

Colonisation rates of signal crayfish are usually around 1–2 km per year on average (Peay & Rogers 1999, Sibley 2000). This can be used as a guide to how soon alien crayfish might come into contact with white-clawed crayfish, although the alien crayfish may be present for a while before they are detected. All the indications are that even in the absence of an outbreak of crayfish plague, once a mixed population of signal crayfish and white-clawed crayfish occurs, the white-clawed crayfish population is progressively lost due to competition. If this happens, there is no known action that can be taken to allow future recovery of favourable condition.

Information on alien species is essential for determining whether a population is in favourable condition and its prospects for the future.

Table 8. Consequences of alien crayfish for conservation status of white-clawed crayfish.

Location of population of alien crayfish	Condition of white-clawed crayfish
Aliens known to be in a watercourse in the catchment and within 20km the white-clawed population.	Unfavourable now, or soon; (expect population condition to be unfavourable and declining)
Aliens are in the same catchment but more than 20km away by water.	Unfavourable condition is a future serious threat
Aliens are present in an adjacent catchment or enclosed water body less than 5 km over land from a white-clawed crayfish population.	Unfavourable condition is a future serious threat
Aliens thought to be absent from catchment with white-clawed population.	Favourable condition

A4.2 Risk of crayfish plague

There is always some risk of plague transmission, but the risks are higher when there are a lot of anglers using a watercourse that has white-clawed crayfish, especially if those anglers are also fishing waters with alien crayfish.

For monitoring it may be appropriate to check the following:

- Number of angling clubs fishing watercourses with white-clawed crayfish population and approximate membership.
- Number of clubs also holding rights to waters with alien crayfish.
- Number of clubs stocking fish from farms/other waters with alien crayfish.

Stocking any fish from waters with alien crayfish within 20 km of a population of white-clawed crayfish in a SAC carries a high risk, especially in catchments with no alien crayfish. It is recommended that for rivers with solely white-clawed crayfish, no stocking of fish should be permitted from waters that have alien crayfish, unless an acceptable disinfection procedure is used. Such procedures are not yet available. All those entering watercourses with white-clawed crayfish should be encouraged to carry out measures to reduce the risk of spreading crayfish plague. In the event of an outbreak of plague it is advisable to minimize access to infected water to reduce the risk of spreading the disease.

If crayfish plague does occur, it is likely to be several years before any re-stocking can be considered. Guidance on stocking is given in Kemp *et al*. (2003). If some crayfish remain in the catchment in semi-isolated populations around the main affected reaches, it is possible for sporadic outbreaks of plague to re-occur at intervals. In other cases, a total kill may be followed eventually by successful re-stocking.

Information on crayfish plague is important for assessing whether there is a significant threat to the favourable condition of a population.

Table 9. Risk of crayfish plague transmission.

Activity	Risk of plague transmission to white-clawed crayfish
Regular stocking, by one or more clubs, with fish from fish farm with alien crayfish.	Very high risk of transmission of crayfish plague.
Many angling clubs and/or regularly fish waters with alien crayfish.	High risk.
Few angling clubs and/or mainly fish waters without alien crayfish.	Moderate risk.
No angling or stocking with fish	Low risk only, from aquatic birds and mammals or casual access by people if alien population nearby.

A4.3 Pollution risk

There is always some risk of pollution in watercourses, but risks are higher where there is a high proportion of urban land in the catchment, road crossings with high volumes of traffic, or close to licensed effluent discharges.

In rural areas sheep dip (especially cypermethrin) is the main risk, although other types of pollution may occur – for example, from organic slurry, dairy washings or silage liquors. The Environment Agency is likely to have a sheepdip monitoring programme underway in the catchments of SSSI/SAC rivers in England and Wales. Individual farm holdings visited are given ratings of high, moderate and low risk of pollution from sheep dip.
For monitoring the condition of white-clawed crayfish it may be advisable to record:

- The number of farm holdings classed as high, moderate, low risk of sheep dip pollution in the catchment of watercourse with white-clawed crayfish.
- Pollution incidents within the past 10 years; the date, type and estimate of the lengths of watercourse affected by recorded, or suspected pollution.

It is not easy to quantify pollution risk in relation to crayfish, but if there is a pollution incident sufficient to cause mortality, the recovery period for crayfish may be several years. White-clawed crayfish only colonise new areas relatively slowly. Colonisation depends on there being a population nearby from which an affected site can be re-colonised.

It may take months to years for crayfish to move back into an area after a pollution incident. Crayfish only breed once a year and the young may take three years or more to sexual maturity. So recovery time could be four to five years, or much longer, because populations tend to build up in a favourable area before there is extensive colonisation to neighbouring areas of the watercourse.

If pollution incidents occur on average one year in 10 or more often, this may prevent use of a watercourse by white-clawed crayfish, or keep the population at low abundance. This would equate to unfavourable condition. Sub-lethal pollution from urban drainage may not cause mortality, but may show up in lower recruitment or higher incidence of disease, for example, thelohaniasis.

Information on pollution risk is considered to be important for understanding whether observed abundance represents the natural potential abundance or not.

A4.4 Land use and erosion

Poaching of riverbanks and bed by livestock leads to greater rates of bankside erosion. This can cause loss of bankside refuges and deposition of fine sediment, which can smother crayfish refuges. Survey methods are not covered here, but the results from any assessments should be considered in relation to crayfish and the condition of habitat for crayfish.

Note that bank modifications may be adverse or beneficial for crayfish (Peay 2003b). Loose boulder or builders' rubble used to reduce erosion on a bend, un-mortared stone walling along the channel, or willow-revetting can offer refuges. Concrete walls or sheet piling cause the loss of refuges in banks.

Information from RHS that may help in the interpretation of results of crayfish monitoring at reach or catchment level may include:

- **Riverside land use** within 50 m of the channel: ungrazed semi-natural vegetation; improved grassland (high stocking rate); other grazing, including moorland (low stocking rate, including grazed woodland); arable, urban, (percentage). Additional categories may be available, but these summarised ones are those most relevant to the likelihood of trampling of banks and channel by livestock and risks of pollution.
- **Tree cover**. Continuous or semi-continuous on one or both banks, trees scattered on one or both banks, or none (percentage length in category).
- **Riverbank fencing**. Unfenced, but not grazed; fully effective fencing; partly effective fencing (some grazing); no fencing and grazed, (m/km both sides and percentage).
- **Eroding banks**. Vertical or poached (m/km both banks and percentage).
- **Other types of bank modification.** It may help to know proportion of banks with modifications unfavourable for crayfish. Some, such as unmortared stone block walls and loose boulders or rubble in the margins, are favourable for crayfish; others, such as sheet piling or concrete walls are unsuitable.

Where siltation occurs, the abundance of crayfish may be reduced, or white-clawed crayfish may be lost from the sample site. In addition, conditions for manual survey become more difficult. Lower efficiency methods, such as use of baited traps, may be necessary to detect whether crayfish are still present. It may be difficult to distinguish how much reduction is due to loss of crayfish and how much to reduction of survey efficiency.

At present it is not known how much poaching, erosion and siltation can occur in different types of watercourse before there is a reduction in the population of white-clawed crayfish. This is a topic recommended for future research.

Information on land use is less important that for the preceding factors. It may be helpful for interpreting crayfish surveys and the results of monitoring.

A4.5 Flow

Flood events are a natural feature of river systems, and aquatic invertebrates are adapted to living in such dynamic conditions. Nonetheless, there are reports of crayfish being washed out and stranded by large floods in some rivers. Any flood event large enough to move the relatively stable refuges used by crayfish is likely to lead to increased mortality, at least at the scale of the sampling site and possibly at reach or catchment level.

If there is an apparent reduction in the abundance of crayfish, information on extreme events may be helpful in the intepretation of results. On site, if a flood has occurred relatively recently there is likely to be evidence such as:

- Boulders showing signs of having been lifted and moved, having unvegetated undersides exposed.
- Refuges that were loose on previous occasions now having interstices packed with sand and gravel.
- Recently scoured banks, islands or side-bars.
- Flood debris at high level on overhanging branches.

Major floods during July-September are likely to cause high mortality in juvenile crayfish.

Data required:

- Date of flood events, probably those of one in five-year return period or greater that have occurred during the previous five years.

Low-flow events are much less likely to have any detectable effect on white-clawed crayfish abundance, unless sections of the channel dry up, leaving crayfish more vulnerable to predation. If this happens it should be recorded and considered in any assessment of the crayfish population.

Flow data are readily available from the Environment Agency for gauging stations in catchments throughout England and Wales. Natural flows are unlikely to cause any loss of favourable condition, but may affect population abundance. Abstraction of surface water or groundwater that led to extensive drying out of a river channel could have a greater effect on the crayfish population.

Porcelain disease (Thelohaniasis) may be present in white-clawed crayfish populations. An infected individual has a distinct opaque underside (right) compared to normal crayfish (left). See page 46 for details.

Both photos by David Holdich

Crayfish plague is difficult to identify in the field (right). Clinical signs include necrotic white musculature on the right side of the anterior adbominal segments (left side of image), as well as in the final segment, and in the musculature of the telson.

David Alderman/CEFAS

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.

Life in UK Rivers

ENGLISH NATURE

Cyngor Cefn Gwlad Cymru
Countryside Council for Wales

Asiantaeth yr Amgylchedd
Environment Agency

SEPA
Scottish Environment Protection Agency

SCOTTISH NATURAL HERITAGE

SNIFFER

The white-clawed crayfish is the UK's only native crayfish. Once widespread across Europe, the white-clawed crayfish is declining throughout its range. Now the populations in the UK represent the largest concentration of the species in Europe.

Major threats to the white-clawed crayfish are introduced crayfish species, which may transmit disease, water pollution and loss of habitat.

This report suggests monitoring methods that can be used to determine whether white-clawed crayfish 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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