KEYNOTE
A COST-LED EVALUATION OF SURVEY METHODS AND MONITORING FOR WHITE-CLAWED CRAYFISH

- LESSONS FROM THE UK -

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ABSTRACT

The white-clawed crayfish *Austropotamobius pallipes* is under threat in the UK and elsewhere in its European range. There is legislation to protect it and a requirement for the status of the species to be monitored. There is a need for a strategy that meets reporting requirements, but allows resources to be targeted to surveys and action that contribute most to the conservation of the species. The paper shows how different objectives lead to differing requirements for information. It takes a cost-led view of survey methods, their benefits and limitations. Using the example of rivers in the UK, it presents an approach to monitoring, in which the priority is the identification of the key threats to white-clawed crayfish. This can inform management decisions about the monitoring to be carried out in future and the options for action in the interests of conservation.

Key-words: white-clawed crayfish, survey methods, cost-effectiveness, monitoring.

UNE ÉVALUATION À COÛT SUIVI DES MÉTHODES D'OBSERVATION ET DE SURVEILLANCE DES ÉCREVISSES À PATTES BLANCHES

- LEÇONS DU ROYAUME UNI -

RÉSUMÉ

L'écrevisse à pattes blanches *Austropotamobius pallipes* est menacée au Royaume-Uni ainsi qu'en d'autres régions de son aire de distribution européenne. Il existe une législation en faveur de sa protection et une obligation de suivi liée à son statut. Mais on a besoin de définir une stratégie qui réponde à des exigences de reportage, et qui permette d'évaluer les ressources en fonction des actions de suivi et des actions les mieux adaptées à la conservation de l'espèce. L'article montre comment des objectifs différents mènent à des obligations d'information différentes. Il adopte une position à coût-suivi des méthodes de surveillance, de leurs avantages et de leurs limites. En utilisant l'exemple des fleuves au Royaume-Uni, il présente une approche de la surveillance, dans laquelle la priorité est l'identification des menaces principales sur les écrevisses à pattes blanches. Ceci peut apporter aux gestionnaires des informations sur le suivi à effectuer à l'avenir et sur les options d'actions dans l'intérêt de la conservation.

Mots-clés : Écrevisses à pattes blanches, échantillonnage, rentabilité, surveillance.

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INTRODUCTION

The white-clawed crayfish *Austropotamobius pallipes* is protected under Annex II of the EU Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC), as a "species of community interest whose conservation requires the designation of Special Areas of Conservation" (SAC). Annex II requires member states to monitor protected species and report every six years on whether each species has "favourable status" across its natural range. This includes assessing whether the species is in "favourable condition" for different attributes, which for riverine species may include water quality, nutrient levels, flow regime, riparian habitat, level of disturbance, absence of threats or other attributes.

The Directive does not specify in any detail what constitutes "favourable status" or "favourable condition". In the UK, work has been undertaken on 13 protected riverine species under the Life in UK Rivers project (http://www.english-nature.org.uk/LifeinUKRivers/), to help improve understanding of the ecological requirements of the species and how their status can be monitored. Ecological requirements for white-clawed crayfish are described in HOLDICH (2003), and a protocol for monitoring the species in rivers has been produced (PEAY, 2003a). The Directive and the legislation in the UK that implements it is a significant driver for monitoring crayfish, both locally and nationally.

Monitoring addresses specific objectives or questions, usually status or change in status in the population, or in environmental or biotic conditions. Surveys are the tool used to carry out monitoring. There is no single "ideal" method for surveying crayfish, but in designing and implementing a monitoring programme at any scale, it is important to select a method or methods that will address the chosen monitoring objectives, within the constraints of environmental conditions and the available resources for monitoring.

This paper is not intended as a comprehensive review of survey methods. Instead, it takes a "management-led" view of survey methods and their use in monitoring. The opinions given are those of the author and do not necessarily represent the policy of statutory agencies in the UK. Emphasis is given to the cost of different survey methods in terms of time and resources, because those responsible for monitoring programmes are likely to consider "how cheaply can I obtain the necessary data to address the objectives?"; or "how much monitoring can I afford to do with the budget available?" This paper is mainly concerned with monitoring the white-clawed crayfish in rivers for purposes of conservation of biodiversity, although some of the discussion may be relevant to other species. Monitoring for management of recreational or commercial crayfish fisheries is not discussed, as the white-clawed crayfish is protected from "taking or sale" in the UK. Furthermore, stock management has been addressed by others, such as WESTMAN and PURSIAINEN (1979); WESTMAN *et al.*, (1993); MOMOT, (1993) and SKURDAL *et al.* (1993).

Reasons for monitoring and how this influences the need for survey data are given. Advantages and limitations of survey methods are outlined, mainly in terms of resources, with some examples. The paper concludes with a strategy for monitoring crayfish in rivers and how this contributes to the conservation of white-clawed crayfish in the UK.

PLANNING MONITORING

Legislation and planning policy are major drivers for monitoring programmes for crayfish in the UK and in other member states of the European Union (EU). Under the EU Habitats Directive (92/43/EEC) member states must monitor and report on the status of protected species. Surveys are needed for a range of parameters, for which there are thresholds defining favourable or unfavourable condition. Figure 1 shows that the need to report on the status of white-clawed crayfish in UK rivers, which are designated as SAC, gives rise to two categories of information. The first is an appraisal of the risks to favourable condition, much of which can be done using information other than surveys for crayfish. The second is information on the crayfish population, including the geographic distribution and whether the population is in favourable condition according to its relative abundance, reproduction and health. Where the crayfish population is widely distributed in the SAC, the survey requirements are quite onerous, because there has to be wide coverage and an indication of the relative abundance of crayfish, or at least a reasonable degree of consistency of recording between rounds of monitoring.

In the UK there has been a rapid increase in number and spread of populations of non-indigenous crayfish species (NICS) in England, Wales and Scotland (SIBLEY *et al.*, 2002, HOLDICH, 2002 and cited authors), although Northern Ireland is still free from NICS. Despite the increase of NICS, the white-clawed crayfish is still widespread, although the range is reducing year by year. Monitoring the white-clawed crayfish throughout its natural range in the UK would require an enormous amount of survey effort if it was carried out everywhere at the same level as in SAC. More reliance has to be placed on assessing the risks to white-clawed crayfish within river catchments and on incidental records from surveys for other purposes. Where the resources to carry out crayfish surveys are available, the agencies responsible (mainly the Environment Agency in England and Wales) have to be selective in the scope of work.

The UK published its own Biodiversity Action Plan and a Species Action Plan for white-clawed crayfish (HMSO, 1995). In the UK, protected species have to be taken into account by local planning authorities when they consider new plans and projects, whether or not a formal Environmental Impact Assessment is required (under the UK regulations that implement the EU directive on EIA, 85/337/EEC). Surveys for projects tend to be localised to a site or individual waterbodies, rather than whole catchments. In re-introduction programmes, however, it is important to carry out an assessment of risks to white-clawed crayfish in the wider catchment as well as locally (KEMP *et al.*, 2003). The

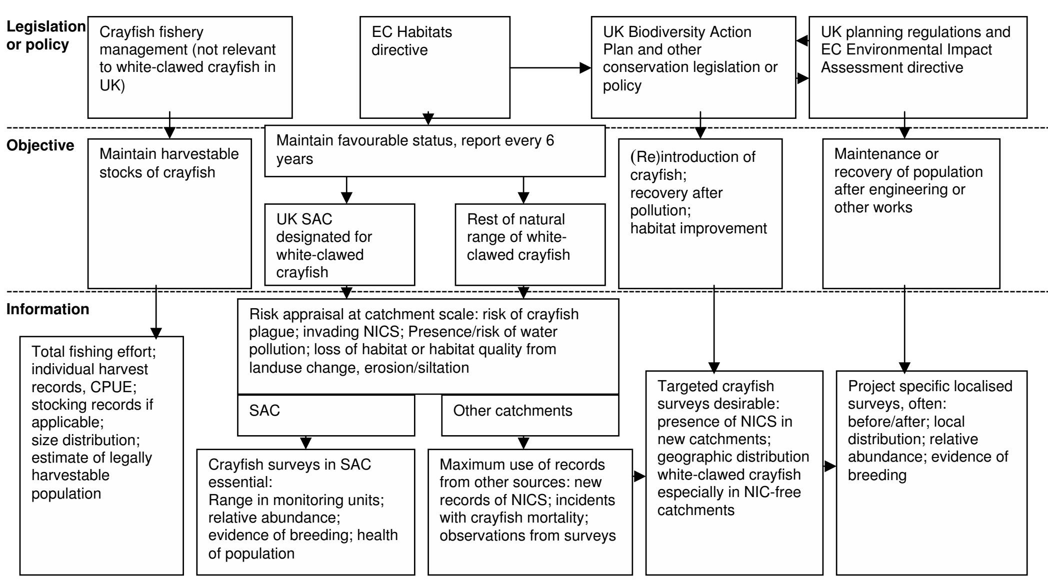

Figure 1

Examples of how policy in the United Kingdom leads to requirements for information about crayfish.

Figure 1

Exemples illustrant comment la réglementation au R.-U. conduit à des obligations d'information concernant les écrevisses.

major issues are whether NICS are already invading the catchment, or may be introduced, plus the associated risk of crayfish plague (*Aphanomyces astaci*). In some catchments, however, pollution from agriculture or urban areas, or erosion and siltation due to land use are major constraints on white-clawed crayfish.

The monitoring strategy depends on the information requirements of different project objectives (Figure 1), the required accuracy, the resources available and the physical characteristics of the habitat to be surveyed. Monitoring programmes that are extensive or comprehensive in their coverage, or use survey methods with high resolution to detect change also have a high cost in terms of time, people, materials, analysis and overall cost. The statutory agencies responsible for monitoring protected species in the UK have limited budgets and the white-clawed crayfish is only one of a suite of species to be monitored. Cost is therefore a major constraint.

SURVEY METHODS

Essentially, survey methods fall into one of three categories, those that depend on crayfish being active at night; those that involve finding crayfish that are hidden in refuges, and surrogate methods. Two methods reliant on active crayfish are traps using baits and night-viewing (observation by torchlight, which usually includes catching crayfish by hand). Methods relying on active crayfish are strongly influenced by factors that affect the activity of crayfish, such as season, water temperature, flow conditions, food availability and behavioural factors, including moulting. Finding crayfish in refuges is predominantly done by manual survey methods, either by selective searching, or by fixed area sampling (e.g. quadrats). Manual surveys by day are usually carried out by wading in shallow water or, in some instances, by SCUBA-diving. Electro-fishing could be considered to be an intermediate method, because crayfish will only be detected if they respond to the electric field by emerging from their refuges. Surrogates provide indirect evidence of the presence of crayfish, e.g. from remains, or are records of crayfish from surveys for other purposes.

Some comparisons of methods using size distributions as a guide to efficiency of sampling the population

All survey methods produce a biased sample of the true population. It is difficult to compare the degree of bias unless two or more methods can be used in the same area of a waterbody. Even then, the distribution of crayfish is patchy, in response to microhabitat and habitat usage varies in different portions of the population, as shown, for example, by REYJOL and ROQUEPLO (2002). If the same habitat is sampled by different methods, the size distribution of the captured crayfish differs from the distribution of the actual population according to the selectivity of the survey method.

PRATTEN (1980) recorded the growth increments at successive moults that contribute to the overall size distribution of the population. As successive cohorts are added to the populations, the size distributions are additive, forming the overall size distribution, with juvenile crayfish forming the bulk of the population. In samples from wild populations, the size distribution usually shows a distribution with more than one peak, with year class peaks higher for males than the corresponding values for females (*e.g.* MORIARTY, 1972, BROWN and BOWLER, 1977, ARRIGNON and ROCHÉ, 1981).

The greater the size bias to larger crayfish, the smaller the proportion of the total population of crayfish sampled by the survey method. Figure 2 shows the size frequency of white-clawed crayfish from Meanwood Beck, a stony stream in Yorkshire, England, obtained by different survey methods during the summer; by trapping with two types of trap, night-viewing and selective manual survey, although the manual dataset is from another similar stream. The number of crayfish in each 2 mm size class (carapace length, CL) is shown as a percentage of the total catch by that method. The T traps are Swedish Trappy® traps (a cylindrical trap 22 cm diameter, with a cone-shaped funnel entry at each end, and a diamond-shaped mesh approximately 20 mm in size), which were baited with mackerel. Survey data for T traps have been analysed from SWINDLEHIRST (2000), with permission. The F traps are fine-mesh funnel traps (GB Nets), 15 cm in diameter, made of 4 mm plastic mesh and baited with sardines in sunflower oil. The night-viewing results are for crayfish on the streambed at night and captured by hand. The crayfish recorded in T traps are in the range 32-53 mm CL, plus a single crayfish of 27 mm CL (n = 126). The modal value is 39 mm CL. The range for F traps is similar at 26-46 mm CL, (n = 111); but the size class with the highest frequency is 32 mm, lower than for T traps. With night viewing, the mode is the same as for F traps, but the crayfish seen (n = 544) were in size classes 8-50 mm CL. More juvenile crayfish were recorded. The manual survey data (PEAY, 2002) shows crayfish in the size range 8-48 mm (n = 1 392). The multimodal distribution is evident, with a mode at 30 mm and the peak at 24 mm.

Figure 2 shows the selectivity of trapping toward the larger size classes, consistent with other studies (e.g. BROWN and BREWIS, 1978). Even trapping with fine-mesh traps, which catch more of the smaller crayfish, has a significantly different size frequency distribution to that for night viewing (a Kolmogorov-Smirnov test of the cumulative distributions of numerical frequency had a maximum difference of D = 0.375, P = 0.05). Only 7% of crayfish recorded by night-viewing and less than 1% of the catch using Trappy

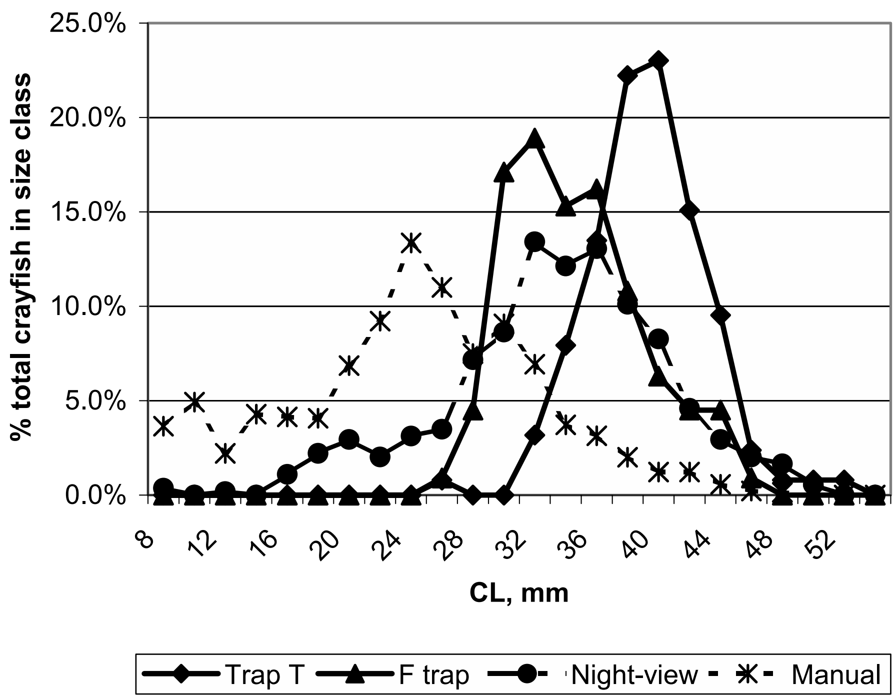

Figure 2

Size distributions of white-clawed crayfish recorded by different survey methods; trapping using two different types of trap, night viewing and selective manual survey, in June-September.

Figure 2

Distribution en classes de taille d'écrevisses à pattes blanches, sur la base de données obtenues à l'aide de différentes méthodes ; pièges utilisant deux types de pièges, observation de nuit et suivi manuel sélectif, de juin en septembre.

traps were less than 30 mm CL, compared to over 70% of those recorded in the manual survey. Even in the manual survey data, the juveniles are undoubtedly under-recorded compared to the true population, which would be expected to have a peak of 0 + and 1 + juveniles at least as great as the total for crayfish of 2 + years and above.

SILVER (2000) carried out a study prior to engineering works in the Huddersfield Narrow Canal, an artificial watercourse fed by Pennine streams that are similar to Meanwood Beck. Intensive trapping at a single 20 m long site on six nights in mid October led to the capture of 60 crayfish from 140 trap nights. The modal size from trapping was 42 mm CL and the crayfish caught were in the range 32-49 mm CL. When the canal was dewatered, three times in succession in November, the total number of crayfish recovered was 549, from the same 20 m of canal. The median size of the rescued population was 24 mm CL (Figure 3). The peak of juveniles at 9-13 mm CL is about 25% of the recorded population. The rest of the size distribution is multi-modal and shows a similar distribution to that found in manual survey. In principle, dewatering of the canal gives the closest approximation to the true population, but in practice, juveniles are under-recorded in the inevitably muddy conditions of a dewatering operation.

In all, 150 crayfish were in the potentially "trappable" size range (> 32 mm CL), 27% of the total population from dewatering. Two pilot surveys of 10 traps/night yielded only 3 and 6 crayfish respectively. This is about 2-4% of the potentially trappable population at the site, or rather less than 1% of the population rescued during dewatering. With more than half the traps recording no crayfish, any survey with fewer traps would have a lower probability of detecting what was subsequently found to be an abundant population.

The comparison of size distributions is not intended to discourage the use of methods with a bias towards larger crayfish. On the contrary, the catch per unit effort

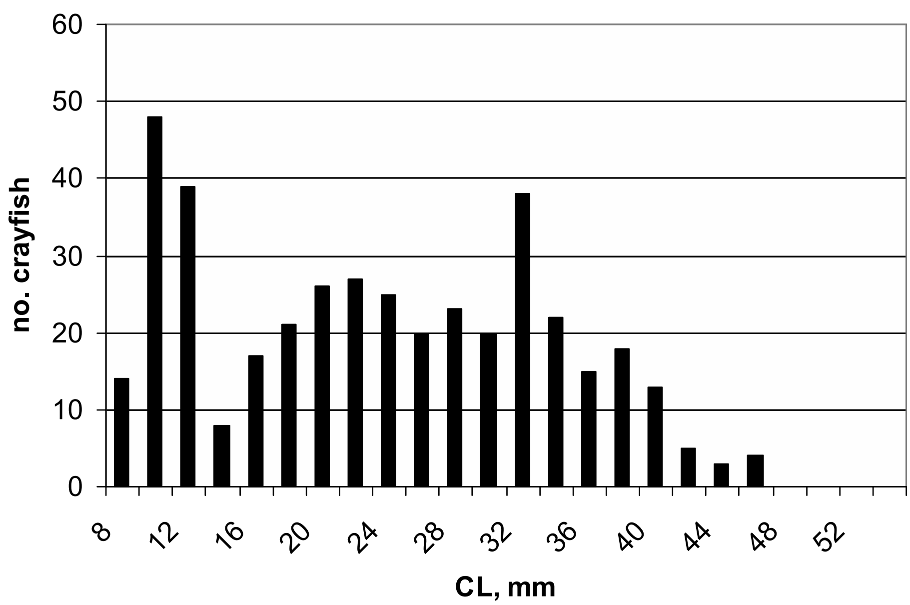

Figure 3

Size distribution of white-clawed crayfish in Huddersfield Narrow Canal, West Yorkshire, recorded by de-watering, mid October (derived from SILVER, 2000).

Figure 3

Distribution en classes de taille des écrevisses à pattes blanches dans le Huddersfield Narrow Canal, West Yorkshire, à partir de données obtenues après vidange, mi octobre (d'après SILVER, 2000).

(CPUE) from trapping has been shown to be an effective method of monitoring change in crayfish populations, (e.g. SKURDAL *et al.* 1995, KELLER, 1999; KIRJAVAINEN and WESTMAN, 1995). Choice of survey method has a major effect on the catch obtained, so methods should be reported in detail. Datasets obtained by different survey methods should be kept separately. If there is a specific need to aggregate catches, analysis of the size frequencies from the different methods should be undertaken in relation to a population model (e.g. LEWIS and HORTON, 1997) and the method of aggregation should be given in detail.

A comparison of methods based on cost

The biggest cost element in any crayfish survey is the labour. Actual sampling time may be less than half the total time required per site, even with manual survey or night-viewing, both of which require a single site visit for each set of survey data. Where cost is a consideration, there will be bias toward crayfish surveys in which the data can be collected in as few site visits as possible, with a small survey team and with inexpensive equipment. Crayfish surveys involve working in or by water and for safety reasons this will almost always require at least two surveyors. Some methods require larger teams. In the UK, regulations on employment of divers specify a minimum team size of three qualified SCUBA divers and the recommendation is for a larger team if there are potential hazards such as underwater snags, currents > 0.25 m s^{-1}, or boats in the vicinity (HSE, 1998). Environment Agency electro-fishing teams consist of at least three staff and there are strict requirements for training and safe operating procedures.

Trapping

The cost of equipment is important in the commercial harvesting of crayfish (JUSSILA, 1995), but is also relevant to surveys and monitoring programmes. Prices for crayfish traps for sale in the UK typically range from £5 to £30, but some types are sold for as much as £115. Theft and vandalism of crayfish traps is a significant issue, especially in areas with public access.

Trapping always requires two visits, to deploy the traps and then retrieve them, plus staff time for trap cleaning and storage. If traps are set from a river bank, the time needed to set the traps may be as long as the time required for a selective manual survey or night-viewing survey, plus the same time, or more, when the traps are lifted. There are additional costs in equipment if traps have to be set from a boat, but greater efficiency of labour if a large number of traps is set on a lake or large river, especially where access to the banks is difficult. EDSMAN and SÖDERBACK (1999) estimated that a pair of experienced operators could set about 100 traps in a day from a boat.

The major advantage of trapping is that it can be used in deep water and is the only effective method for use in turbid conditions. Its popularity as a survey method means there is a wealth of available literature and methodological detail. It can often be done without the need for surveyors to enter the water, a safety benefit, which may enable surveyors to work for longer periods than during a manual survey.

The size-selectivity of traps and the seasonal variations in trappability (e.g. FENOUIL and LEGIER, 1977; BROWN and BREWIS, 1978; ABRAHAMSSON, 1981; WESTIN and GYDEMO, 1988; RACH and BILLS 1989; REYNOLDS and MATTHEWS, 1993; FRUTIGER *et al.,* 1999; WRIGHT and WILLIAMS, 2000) means that trapping techniques should be standardized as much as possible. Seasonal variation can be reduced by trapping in late summer to early autumn, when adult crayfish have finished breeding and moulting, but before falling water temperature reduces activity and lowers catch efficiency. The standardization should include trap type, bait, and the location of traps.

ABRAHAMSSON and GOLDMAN (1970) estimated an effective trapping radius of 2.5 m, whilst ACOSTA and PERRY (2000) estimated 4 m. Currents may lead to variation in the effective trapping radius. Overlapping effective radii will reduce the catch per unit effort. Localised variation in habitat suitability for crayfish markedly affects trapping efficiency. Placement of traps in slow-flowing margins of rivers, beside complex banks or riverbed with abundant refuges, will produce a higher catch than traps set in less favourable habitat. Night viewing of signal crayfish *Pacifastacus leniusculus* in a river in Yorkshire has shown (author's observations) that active crayfish move into refuges if velocity increases, hence trappability and CPUE is reduced. Surveys dependent on active crayfish should certainly include records of water temperature and, in rivers, the flow conditions.

CPUE from any trapping sessions longer than one night are not directly comparable with those from a single night, unless some calculation is made of the rate of loss or gain of crayfish in longer periods. Few, if any, traps are completely escape-proof, and trap retention varies considerably, as indicated by BEAN and HUNER, (1978), FJÄLLING (1995), CAMPBELL and WHISSON, (2002).

Night-viewing

This method of spotting and catching active crayfish has been used by FENOUIL and LEGIER, (1977); ABRAHAMSSON, (1981); LAURENT, (1985); SÖDERBACK, (1995), ARRIGNON *et al.,* (1999), and GARCIA-ARBERAS and RALLO, (2000), to name a few. It can only be used in clear water and, unless SCUBA-diving is used, the water must be shallow enough for wading safely. It has the benefit of providing counts of active crayfish per unit area, but is affected by the habitat and is less effective if there are deep layers of cobble and boulders, or a lot of macrophyte growth. Like trapping, it enables crayfish to be detected in areas that are not suitable for manual searching, for example when the only suitable refuges are in the banks. It has the advantage that only one site visit is required per dataset, but at least one advance visit should be made in daylight to check for safety hazards on the banks or in the water. It is better suited to monitoring at individual sites over time, or intensive studies of seasonal activity and behaviour (PEAY, unpublished data; GHERARDI *et al.*, 2001), rather than in widespread programmes to determine the geographic range.

The time-costs of surveys differ between methods. The author regularly carries out night viewing in 100 m of Meanwood Beck in West Yorkshire. This takes 1 to 2 ½ hours on site, depending on the number of active crayfish and whether any marking is being undertaken. With travel time, each session requires about 3 ½ hours. A typical 10-trap survey at the same site takes at least 6 hours including two lots of travel time. A survey with the maximum number of traps (28) takes over 9 hours in total and yields a catch similar to night viewing. Canals generally have very good access along the towpath along one bank. SLATER *et al.* (2001) surveyed sites on a canal at 1-2 km intervals, deploying 5 traps per site. With half a day spent lifting traps and the rest setting them, the two-person team achieved a work rate of about four sites a day. Lower rates may apply on rivers, where access is often much more difficult.

Many mark recapture studies have been carried out to provide estimates of population size, or rather, the proportion of the population amenable to sampling by the survey method. SUTHERLAND (1996) provides a general introduction to the techniques. PARTANEN and PENTTINEN (1995) describe some of the problems with the assumptions made in mark recapture estimation. They emphasise thorough mixing of marked and unmarked animals cannot be assumed, instead local dispersal occurs. Even in closed populations there are difficulties in the use of the various models. The issue is not discussed in any detail here, because mark recapture requires a minimum of two sessions of data-collection and usually more. It is an expensive method, and best suited for research studies at a specific site. Mark recapture studies also have a role in the comparison of survey methods. In the UK at least, a semi-quantitative estimate of the population, as a catch per unit effort, is sufficient for most monitoring programmes.

Manual survey

Manual survey comprises fixed area sampling and selective manual searches. Fixed area sampling has been carried out with a range of quadrats, Surber samplers and other types of sampler (e.g. GUAN and WILES, 1996; BYRNE *et al.*, 1999; ODELSTROM, 1981; SPINK and FRAYLING, 2002). In general, manual survey methods are limited by the requirement for clear water for surveyors to see and catch crayfish, although a hydraulic dredge-sieve operated by divers (ODELSTROM, 1981) may help to overcome the problem of sampling in silty conditions.

Manual surveys involving SCUBA diving require trained and experienced staff, who may be more expensive to employ, at least if contractors are used. They also require more gear, which has to be bought or hired. Safety requirements limit the duration of surveys and hence the number of sites that can be surveyed in a day or night. Nonetheless, diver surveys are the only method, besides trapping, for working in lakes. Because of the size selectivity of trapping and the avoidance of traps by berried females, SCUBA surveys are probably the most effective way of obtaining information on recruitment in deep waters.

Fixed area sampling has the advantage of providing a population density in the habitat sampled and it is usual to take several samples per site. It is therefore well suited for detailed studies of populations.

In Scandal Beck, Cumbria (PEAY, 2002), two surveyors carried out fixed-area sampling in shallow water (less than 50 cm deep). The surveyors determined the abundance of all crayfish in an enclosed 1 × 1 m quadrat in 30-45 minutes, by removing all potential refuges from the stony bed of the stream. Overall, 5 quadrats in a single area of slow-flowing channel took a little under 4 hours to record. By contrast, selective manual searches in 100 m sites in the same stream (the method shown in Figure 4) typically took 70 minutes (range 40-100 minutes) for two surveyors, including all recording of crayfish and habitat. Not surprisingly, sites with crayfish at high abundance (the majority in this high quality stream) took longer to record than those with few or no crayfish, especially where there were more than 10 crayfish/10 refuges. Sites with relatively few favourable refuges that could be searched manually took less time to survey than more structurally complex sites.

Manual surveys for a fixed time interval are not a good basis for any monitoring programme. The number of refuges searched per unit of time varies greatly according to the availability of refuges that can be physically searched, the depth of water, its colour, the amount of silt disturbed during sampling and the presence of plants and this makes comparisons between sampling occasions difficult, even at a single site. Sampling on the basis of number of refuges is preferable, as the catch is independent of the time required to search the refuges, or largely so. A standardised selective manual search (Figure 4) provides a relative abundance of crayfish (average number/10 refuges, or habitat patch). This CPUE is not the estimate of crayfish density that can be obtained from fixed area sampling, but standardised selective manual survey has a much lower labour cost.

All manual surveys have the advantage of providing a dataset from a single visit. The maximum working depth is about 40-50 cm, unless the surveyors are equipped with SCUBA-gear. This restricts manual survey without divers to streams and the margins of larger rivers. This would be a problem if the aim was to determine the abundance of crayfish in all habitats within a waterbody, but for many purposes selected surveys of habitat are sufficient. For information on the distribution of crayfish, the most cost-effective strategy is to target the most favourable habitats for crayfish that can be surveyed with the chosen method. If crayfish are not found to be using the best habitat, they are unlikely to be in the less favourable habitats.

In principle, if detecting presence is sufficient, selective manual survey could cease as soon as a crayfish was found. This might be at the first refuge selected in an area with

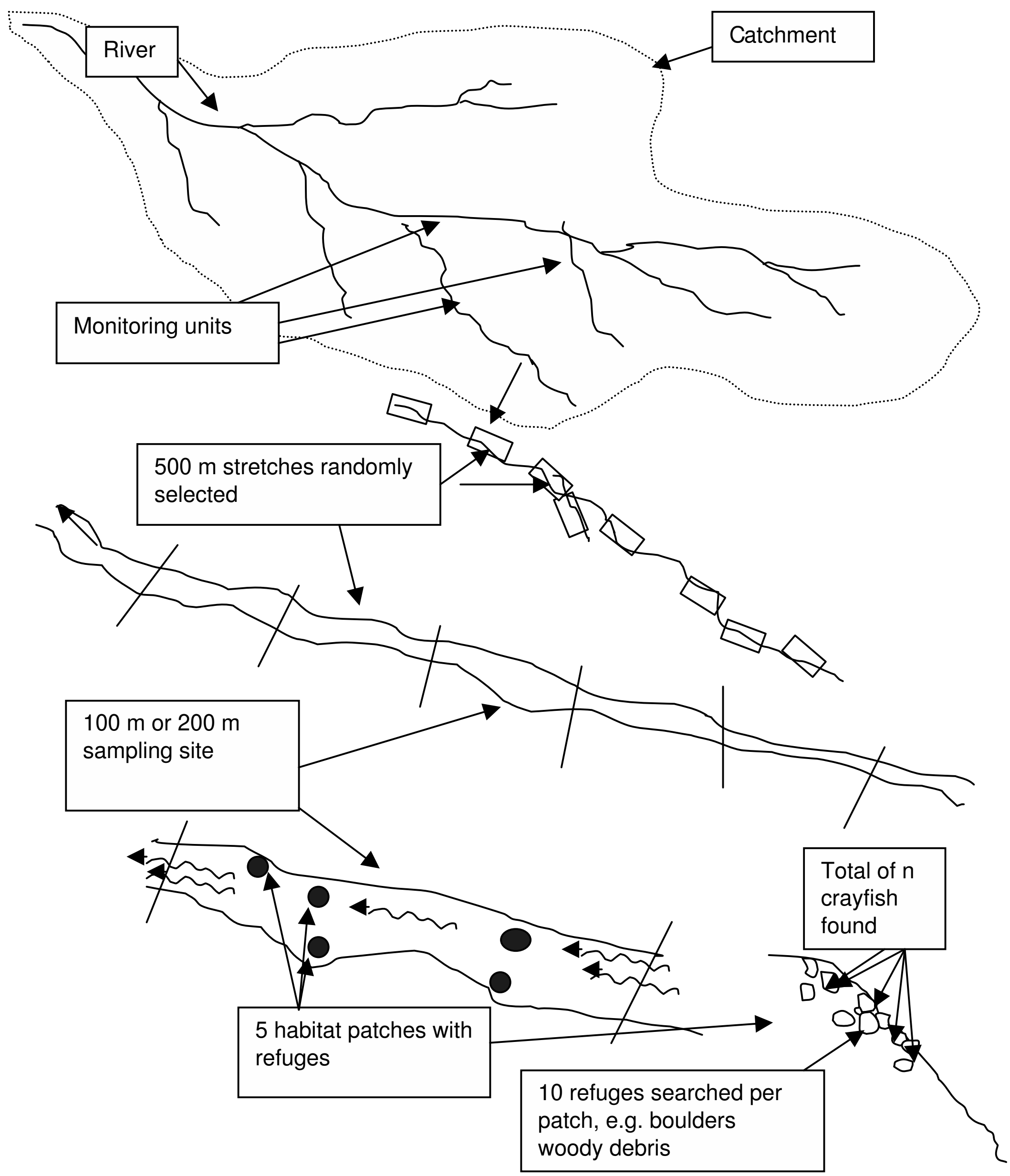

Figure 4
Schematic diagram of monitoring protocol (PEAY, 2003).

Figure 4
Diagramme schématique du protocole de suivi (PEAY, 2003).

high abundance, or just by chance if the population is at low abundance. Even if crayfish are found quickly, there is only a small time saving in omitting a standardised search, because the preparation and the time to get to the site is usually the biggest component of the survey. Analysis is more complex if the degree of survey effort is not standardised.

Where conditions are suitable, selective manual survey in shallow water has major cost-savings over diver surveys in deep water and over fixed area sampling in shallow water.

Electro-fishing

Electro-fishing has been used successfully to survey for crayfish (WESTMAN *et al.*, 1979; EVERSOLE and FOLTZ, 1993), provided it is carried out in shallow water (less than 0.5-0.8 m) in clear water and good weather (WESTMAN *et al*., 1979). The advantages over trapping are that smaller adults and juveniles are caught, the catch is related to a defined area and the survey requires only one site visit. EVERSOLE and FOLTZ (1993) obtained good depletion estimates of crayfish populations, but with a team of five surveyors, it was relatively expensive in labour. As with electro-fishing for fish and manual survey for crayfish, the habitat affects the "catchability". LAURENT (1985) reported problems of under-recording because the crayfish stayed in their refuges and so were either not stunned, or were not readily captured.

The electro-fishing equipment used also affects the survey efficiency for different species of fish or for crayfish. ALONSO (2001) obtained good catch rates, using specially modified equipment at a low voltage (30-50 V, rather than the more usual 300 V). The survey rate in shallow water was relatively slow, an average 0.75 m^2/min, compared to 22.5 m^2/min for fish, but the rate was very much faster than for fixed area sampling for crayfish and compared favourably even with selective manual searching. ALONSO (pers. comm.) found that when using pulses of only 1-2 seconds and low voltage, crayfish would walk out of their refuges. In this respect, it would be useful in streams where refuges were too large or embedded for manual searching.

Electro-fishing gear ranges from £100s to £1 000s, so the start-up costs are high. Crayfish surveys are not carried out using electro-fishing in the UK, although Environment Agency fisheries teams regularly use electro-fishing to assess fish stocks in rivers. Even in rivers known to have high abundance of crayfish, few have been recorded during routine fisheries surveys, although this may be because crayfish were not always reported. The fisheries surveys are not a method for monitoring crayfish populations, but any incidental records of crayfish are free data and may prompt more detailed investigations.

Surrogates

Surrogate methods do not allow quantitative assessment of crayfish populations, but they can be an important way of detecting crayfish populations in waterbodies where no crayfish surveys have been carried out in the "rest of the natural range" (Figure 1). An example is recording crayfish from evidence of predation, usually by mink (*Mustela vison)* or otter (*Lutra lutra)* (SLATER and RAYNER, 1993; ARMITAGE, 2000). This is obviously dependent on the presence of predators, but if surveys are being undertaken for these mammals anyway, the remains on the banks or in faeces can indicate the presence of crayfish without any additional survey cost.

Routine fisheries surveys using electro-fishing, or seine netting of fishing lakes may produce incidental catches of crayfish. Anglers may inform fisheries officers or water bailiffs about crayfish taking angling bait, or present in the guts of fish, or crayfish may be found dead following pollution incidents. The Environment Agency has several thousands of monitoring sites for biological water quality in England and Wales and crayfish are occasionally detected, although the sampling method is not well suited to crayfish. Samples are usually taken in riffles by kick-sampling, plus a very short manual search. Fast-flowing, shallow riffles are less favourable habitat for white-clawed crayfish than slower-flowing glides and pools (SMITH *et al.,* 1996; PEAY, 2003b), so the chance of detecting crayfish is low.

The signal crayfish is well known for its burrowing behaviour, but white-clawed crayfish also burrow, when there is sufficient clay in the substrate and refuges in the channel are limited (PEAY, 2002). Crayfish burrows can at least indicate presence of crayfish, although occupation or species may be uncertain. Crayfish burrows may be spotted during surveys for water vole *Arvicola terrestris*, which involve close inspection of riverbanks, usually from the channel.

The two key points about surrogate surveys are firstly that they are undertaken for other purposes, so any records of crayfish are “value-added”, at little or no additional cost. Secondly, the records only have a value if they are added to a crayfish database locally and nationally and are used to inform decisions about future surveys for crayfish.

AN APPROACH TO MONITORING

In many rivers with white-clawed crayfish, a standardised manual survey will provide sufficient data to determine distribution and to monitor the condition of populations over time. Not all stretches may be surveyable, but it is likely to be more cost effective to omit occasional stretches that are unsuitable for manual survey than to start a trapping programme, which needs two visits per sample. If the number of stretches is too low for adequate coverage, trapping will need to be used, or reduced coverage and lower accuracy accepted.

Where river habitat has been surveyed in advance, this can indicate the likely “surveyability” of the watercourse and hence whether manual survey, trapping, or both should be used in surveys. For some waterbodies, trapping is the only option, because of consistently deep or turbid water, or the refuges only being in the banks. In this case too, a standardised approach is necessary to enable any comparisons between sites or occasions. Just as much care is needed in selecting areas to trap as is used in selecting habitat patches for standardised manual survey. Standardisation and good on-site recording are essential. EDSMAN and SÖDERBÄCK (1999) emphasised this with regard to stock evaluations in Swedish lakes and they proposed standardisation of trapping effort according to the area of lakes. The approach in UK rivers for conservation of biodiversity differs in detail, but the aim of comparability over time is the same.

Figure 4 shows an approach to sampling white-clawed crayfish populations in rivers from the catchment scale down (PEAY, 2003a). It was designed for rivers that can be surveyed manually, at least in part; but the approach would apply equally well if trapping was used, for example, with at least one trap in each of 5 habitat patches (although setting 10 traps/site would improve the detection of populations at only moderate abundance).

The number of stretches to be surveyed in each round of monitoring depends on the variability of the crayfish population and the accuracy required. For the confidence interval on the sample mean abundance (the CPUE, by any selected method) to be within x% of the population mean, the number of sites to be surveyed (n) can be estimated as follows: $n = (2 \times cv \times 100)/x)^2$ (where cv = the ratio of standard deviation to mean).

The recommended approach is to carry out each round of monitoring over two years, to address any limitations of survey efficiency in individual years, for example because of wetter or drier than average seasons. In successive rounds of monitoring, it is possible to keep using the same stretches and sites, but this will not show whether there are problems, such as localised pollution, in the intervening sections. The recommended monitoring strategy in the UK SAC rivers is to re-survey half the stretches and add the same number of new, randomly selected stretches in each round of monitoring. This allows direct comparisons in stretches over time, combined with progressive coverage of the watercourse.

Surveying sites with easy access may keep costs down, but may introduce unknown biases. Hence, random selection of stretches for monitoring is recommended, but with the surveyors selecting the best sites for a crayfish survey within each stretch. In rivers that have a national designation for nature conservation in the UK, riparian owners and occupiers are all known. In other rivers, finding the owners or occupiers can be a time-consuming process and where crayfish surveys are being carried out for the first time, obtaining permission for access may be a significant constraint. Some compromises may be necessary in selecting survey sites.

With limited resources, the monitoring strategy should be targeted to the national and local objectives for species conservation. The decision trees in Figures 5 and 6 show how resources for monitoring could be targeted to maximise conservation benefits. If there are historic records of white-clawed crayfish, there is a need to assess the risks to them in the watercourse and the wider catchment (Figure 6). Specific crayfish surveys can then be carried out and the information used to design a future monitoring programme, if required. Figure 6 shows the key risk issues for white-clawed crayfish (pollution and adverse landuse, crayfish plague and NICS) and the implications for conservation and monitoring. Pollution or land use problems can be addressed, to allow natural or assisted recovery of white-clawed crayfish populations. Recovery projects should include some provision for baseline surveys and monitoring. With crayfish plague there is the potential for restocking, but only if the risk of another outbreak was relatively low; otherwise time and money spent on restocking would probably be wasted.

There are no methods for eradicating unwanted populations of non-indigenous crayfish species in rivers, or even reducing their rate of spread, so once an invading population of NICS is living wild in a catchment, the prospects are bleak for the longterm survival of white-clawed crayfish populations locally. PEAY and ROGERS (1999) showed the progressive local extinction of a population of white-clawed crayfish from competition with an apparently "plague-free" population of signal crayfish. Once a NICS invades, there

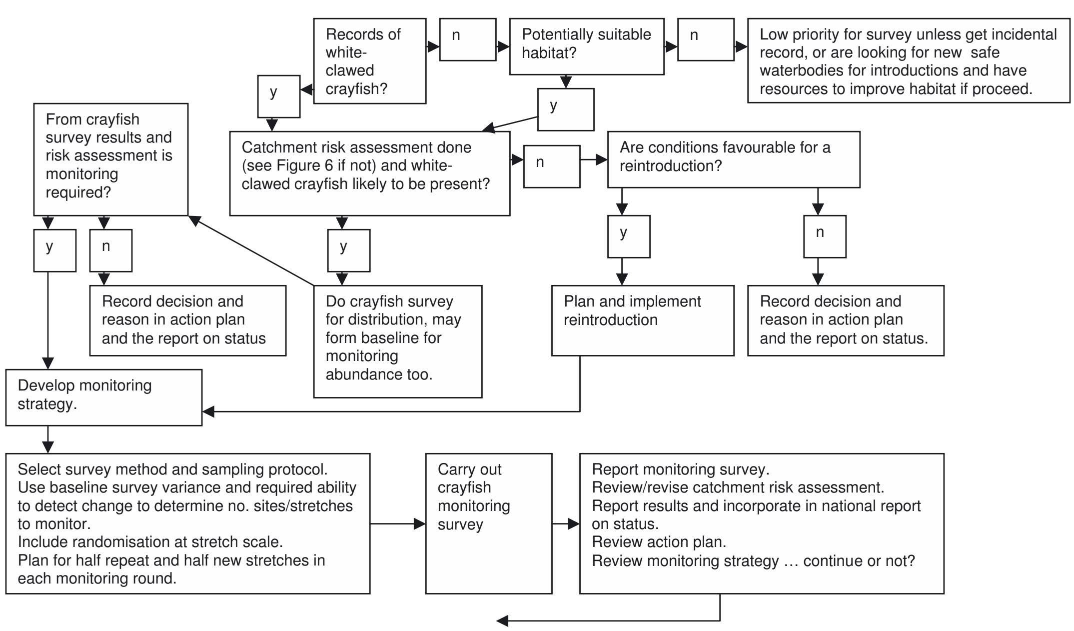

Figure 5

Example of how conservation objectives may direct survey and monitoring for white-clawed crayfish in rivers.

Figure 5

Exemple de la façon dont les objectifs de conservation peuvent orienter l'observation et le suivi des écrevisses à pattes blanches dans les cours d'eau.

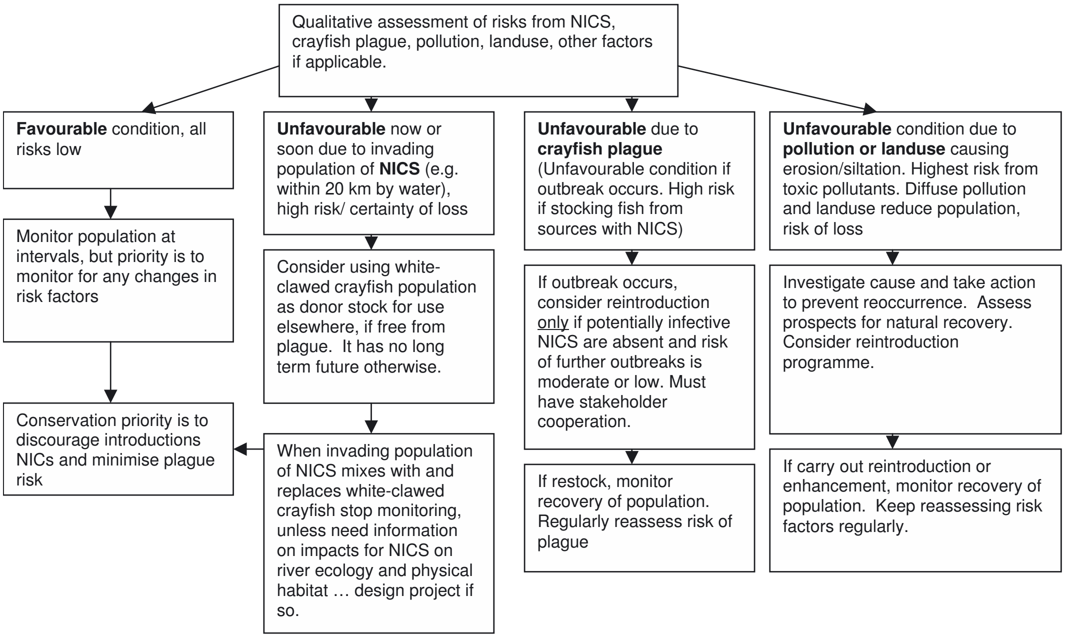

Figure 6
Example of catchment risk assessment for white-clawed crayfish in rivers.

Figure 6
Exemple de l'évaluation des risques sur un bassin versant pour les écrevisses à pattes blanches.

is little value in continuing to monitor the crayfish populations, unless there is the possibility of relocating a proportion of the white-clawed crayfish ahead of the invasion front to a new, "safe" site, away from the NICS, as advocated by HOLDICH *et al*. (2004). Instead, survey efforts may be better concentrated on finding hitherto unknown populations of white-clawed crayfish in small, isolated catchments, in the hope of safeguarding them.

In the few and declining number of river catchments in England with known, abundant populations of white-clawed crayfish and no known NICS population, monitoring may be a statutory obligation, but the priority for species conservation is to identify risks in the catchment and carry out whatever action is possible to prevent or minimise them. Surrogate methods have an important role in identifying threats. For example, there might be anecdotal reports from anglers of NICS in an on-line fishing lake. Knowledge of this might prevent efforts being wasted a few kilometres downstream on re-stocking white-clawed crayfish after a pollution incident. Monitoring is not an end in itself, but rather a tool to help environmental managers and others take management actions that will give the best prospects for the survival of the indigenous species.

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