Monitoring the White-clawed Crayfish

Field-testing in River Eden Tributaries, Summer 2002

Conserving Natura 2000 Rivers

MONITORING PROTOCOL FOR WHITE-CLAWED CRAYFISH

FIELD-TESTING IN RIVER EDEN TRIBUTARIES, SUMMER 2002

Life in UK Rivers
Contract No. LIF 02-11-37

October 2002

Report Author
Stephanie Peay

15A Longwood Avenue
Bingley
West Yorkshire BD16 2RX
Telephone: 01274 511637
Email: crayfish@brydens.org.uk

PROJECT TEAM
Surveyors
Stephanie Peay
Jill Wright
Pete Hiley
Liz Locke, English Nature, Kendal
Biostatistician
David Hirst, Norsk Regnesentral (Norwegian Regional Computing Centre)

This report was produced as part of the LIFE in UK Rivers Project - a joint venture involving English Nature, Scottish Natural Heritage, Countryside Council for Wales, Environment Agency, Scottish Environmental Protection Agency and Scottish and Northern Ireland Forum for Freshwater and Environmental Reasearch and the finacial support of the European Commission's LIFE Nature Programme.

CONTENTS

MONITORING PROTOCOL FOR WHITE-CLAWED CRAYFISH FIELD TESTING IN RIVER EDEN TRIBUTARIES, SUMMER 2002

SUMMARY

This report describes the field-testing of a monitoring protocol for white-clawed crayfish in UK rivers. The aims were to determine the variability in abundance of crayfish related to different factors, including watercourse, stretch, site and surveyor. This information was used to recommend a monitoring strategy for the River Eden and Tributaries SSSI/SAC in Cumbria. It has also been used in the refinement of the overall monitoring protocol for white-clawed crayfish.

The survey method used was within randomly selected 500m stretches to survey sites of 100m, or 200m if required in a large river. Surveyors selected 5 patches of habitat potentially suitable for crayfish and searched 10 favourable-looking refuges in each patch. The abundance of crayfish was expressed as an average number of crayfish/ 10 refuges.

The fieldwork was carried out in two different tributaries. Scandal Beck is a small, limestone stream with a high abundance of crayfish. The River Lowther is a larger river, with more variety of habitat, including upland pasture.

The main findings of the study are:

- The method can be used in a wide range of condition.
- The difference between stretches is the most important component of variance. Hence it is best to sample one site per stretch and survey more stretches.
- Results are affected by the experience of individual surveyors, but the effect can be reduced by using surveyors trained in the use of the method, practicing the method at the start of any field programme and ensuring that surveyors work in groups of two or more.
- The survey method is not sex-biased. All sizes of crayfish are recorded. Juveniles are slightly under-represented because the method involves searching the best habitat, which is used preferentially by adult crayfish.
- Juvenile crayfish 1+ and above represented 47% of the catch in both rivers, using the survey method. Populations are breeding in both rivers, with no sign of any abnormal size distribution.
- Incidence of disease is low in both tributaries, indicating healthy populations, porcelain disease was found in only about 2% of the catch.
- No alien crayfish were found and none are known in the catchment.
- White-clawed crayfish were found throughout the lengths of the River Lowther and Scandal Beck within the SSSI.
- Crayfish were found at very high to high abundance in Scandal Beck and moderate to high abundance in the River Lowther.

- Approximately 1.5km of Scandal Beck had low abundance of crayfish and appeared to be affected by past pollution, although there was no indication of poor water quality at the time of the survey. Because of this, the stream was considered to be in unfavourable condition, but recovering.
- An analysis was undertaken to show the effects on survey results of taking different numbers of samples in monitoring units comparable with Scandal Beck and the River Lowther. The number of sites to be surveyed depends on the accuracy required.
- The current recommendation is for 16 sites per monitoring unit for a baseline survey, then half that number for monitoring. A monitoring unit is any length of river for which monitoring is required, typically a tributary or extensive reach, usually 10km or more.
- It is recommended that the monitoring effort required in any one monitoring unit is divided between two or more years. Although a single series of sites could be used, it is preferable to divide monitoring effort between previously surveyed sites and new ones. A rolling programme of monitoring is recommended, although this should comply with the national guidance on monitoring in SAC sites, namely that a monitoring cycle should not exceed three years within a 6-year reporting cycle.
- Recommendations are made for additional annual monitoring at selected representative sites to determine variation over time.
- Details are given of the time required for surveys to allow estimates to be made of the survey effort required for baseline survey during the first 3 years and for subsequent monitoring cycles.

MONITORING PROTOCOL FOR WHITE-CLAWED CRAYFISH FIELD TESTING IN RIVER EDEN TRIBUTARIES, SUMMER 2002

1. AIMS AND OBJECTIVES

This project was undertaken as part of the Life in UK Rivers Project. The aim was to test and validate the monitoring protocol for white-clawed crayfish. The specific objectives were:

1. To validate a replicable survey method that tests the abundance of crayfish and overcomes the deficiences of timed searches and fixed area sampling.
2. To determine the variability between surveyors and between occasions.
3. To determine the variability between sites in a watercourse with an abundant population of crayfish.
4. To compare sites on a watercourse where habitat characteristics or landuse are less favourable for crayfish and/or less easy to survey.
5. To develop a monitoring strategy for the River Eden and tributaries.

The River Eden SSSI/SAC in Cumbria was used for the study. Cumbria has many watercourses with white-clawed crayfish and to date there are no records of alien crayfish or crayfish plague.

2. METHOD

2.1 Choice of Study Area

The River Eden is a large catchment that drains much of eastern Cumbria. The geology is varied, but several of the tributaries have limestone exposed in their sub-catchments. Tributaries were chosen using the crayfish records for the Eden, held by English Nature and the Environment Agency in Cumbria, together with advice from Maggie Robinson, English Nature, Kendal.

Scandal Beck was chosen as an example of a stream with a good population of crayfish in at least part of its length (suitable for objectives 1 and 2). The River Lowther was also chosen as an example of a larger tributary, with greater variety of form and landuse (for objective 3). In both cases there was some information on the distribution of crayfish, but no surveys of abundance. Both watercourses had been surveyed using River Habitat Survey (RHS), (Environment Agency, 1997). The 500m RHS sections covered approximately 50% of the total length of each tributary. They were used in the crayfish survey because they had already been randomly selected.

2.1.1 Prior information on Scandal Beck

Approximately 10km of Scandal Beck lies within the SSSI/SAC. Some typical views of the stream are shown in Plates 1-8 at the end of the report. Several small headwater streams converge upstream of Ravenstonedale, some 3-6km from their sources, but these are not included in the SSSI. A crayfish survey involving short, timed searches was carried out in 1995. This and ad hoc records from biological water quality sampling suggested crayfish had a scattered distribution along the length of the stream. No quantitative surveys had been carried out. Crayfish were known to be abundant in Smardale Gill National Nature Reserve, a

wooded limestone gorge and disused railway managed by Cumbria Wildlife Trust, about 6km upstream of the confluence with the River Eden.

Scandal Beck is relatively small, classed in the flow category <0.31cumecs by the Environment Agency. Much of the upper part of the catchment is on soft limestone and water quality is assessed as Excellent, Class A. The channel bed is predominantly cobble and boulder at most of the sites, with some areas of bedrock. The channel includes a range of habitat features. It is mainly 5-10m wide, with extensive areas 0.5m deep or less and few places more than 1m deep.

2.1.2 Prior information on River Lowther

There is over 25km of the River Lowther within the SSSI/SAC. Most of the Lowther is on soft limestone, which is generally covered by clay, but is exposed at the surface in a few areas (Parsons *et al*, 2001). The headwaters drain in to Wet Sleddale Reservoir (outside the SSSI). Downstream, the Lowther is a stony stream running through upland, marshy pasture. Further downstream adjacent landuse is predominantly improved pasture and silage leys. Two tributaries enter near Bampton. The larger one, Haweswater Beck, is a regulated stream from Haweswater Reservoir. The river is relatively large, mainly 15- 20m wide or more and with the mid channel in excess of 1m deep in many areas. The river flows for a short way through a broad valley, before descending through a narrower valley, flanked by pastures and estate woodlands, before joining the River Eamont at Brougham. Some views of the river are shown in Plate numbers 9, 10 and 12 at the end of this report.

Information on crayfish was rather sparse. In 1995 11 sites were surveyed by short timed searches. Low numbers were recorded at 3 sites. There were ad hoc records for a number of other sites in the river. The only intensive crayfish survey was on Haweswater Beck. A search of 100 stones was carried out in a 200m site on two occasions in 1998, with 19 and 26 crayfish recorded (i.e. approximately 2 crayfish/10 refuges).

2.2 Survey Method

English Nature obtained permission for access to sites prior to the survey.

At each site, the survey method involves the selection of five patches of in-channel habitat considered to be most likely to have refuges used by crayfish. In each patch a surveyor searches 10 stones, including any underlying material, and records the number of crayfish found. Details are recorded of the habitat in each patch, the conditions at the time of the survey and an evaluation is made of the availability of habitat.

The recommended method is described in detail in the monitoring protocol for white-clawed crayfish (Peay, 2002). It is summarised in the diagram in Figure 2.1 and the terms are explained below.

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 10km in length.

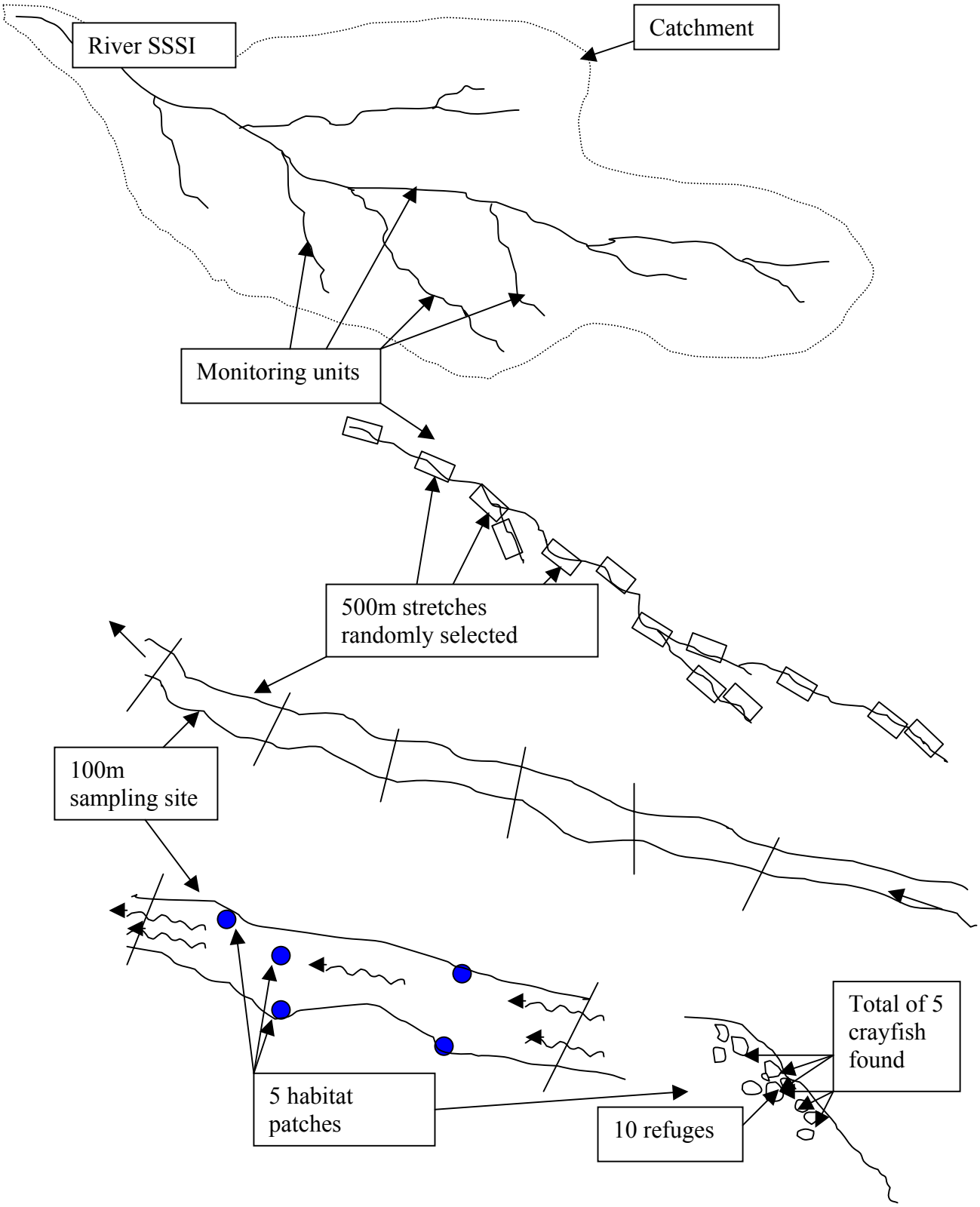
- **Stretches** of river 500m in length are used for selecting sites to survey. They may be 500m sections previously surveyed using River Habitat Survey, but any randomly selected stretches can be used.
- The **sampling site** is a short length of river where the crayfish survey is carried out, usually 100m, but may be 200m 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 $1m^2$ and may be up to about $20m^2$. Patches are generally at least 5m apart.
- The individual **refuge** within a patch, is the basic unit of survey. It is usually a boulder (>25cm) or large cobble (15-25cm). 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.

In the field-testing of the monitoring protocol in the Eden tributaries, the 500m stretches were randomly selected, as recommended in the final monitoring protocol. Randomly selected stretches had previously been derived for use in a River Habitat Survey.

The selection of sites within stretches differed. In the final protocol the recommendation is for a single site to be surveyed in each selected stretch. During the field-testing it was important to determine the variability within and between sites and stretches. Hence every stretch was subdivided into five 100m subsections, identified by the RHS section number and a letter code from A-E, from the downstream end of the section. At least two sites and up to five were surveyed in every stretch.

In general, two surveyors worked on each site, completing two or three patches each. On some occasions, especially at the start of the field programme, three surveyors worked together, again all recording patches individually. The only sites where surveyors worked alone were on the replicate trial described in section 2.3.2 below.

Figure 2.1 Schematic Diagram of Monitoring Protocol



2.3 The Study

2.3.1 Training/practice session

Some preliminary fieldwork was undertaken on tributaries of the River Wharfe, Yorkshire, leading to development of the survey forms. A training session was held in Scandal Beck in Smardale Gill. The surveyors for the project and some local staff from English Nature and Environment Agency in Cumbria took part in the training. The session covered health and safety, the survey method, recognition of habitat patches, selection of refuges and completion of recording forms. Fixed area sampling by quadrat was also demonstrated.

2.3.2 Replicate trial

The purpose of the replicate trial was to investigate the variability between surveyors and occasions at a series of six sites. Four different surveyors took part. Two surveyors at a time surveyed three sites each in one day and the other three sites on a different day. Each site was surveyed on four different occasions, each time by a different surveyor.

The sites were measured at 100m in length and the starting and finishing points of each site were marked using a series of red plastic pegs pushed into the bank. These were left in place until all the replicate surveys were completed. In addition, one of the surveyors who marked the sites briefed each surveyor about the location of the sites and access to them at the start of their first survey.

A stretch of Scandal Beck downstream of Smardale Gill NNR was chosen for a replicate trial because:

- It was expected to have a good enough population of crayfish to avoid nil returns and allow a range of results.
- It had reasonably good access to all the sites.
- It was considered to be safe enough to allow two surveyors to work in separate 100m sections.
- The survey effort required was feasible for individual surveyors to complete in a day.
- The sites were representative of the habitat occurring within the watercourse.
- There was extensive suitable habitat for crayfish and it was robust enough to cope with several surveys without causing excessive damage.

The replicate trial was set up as follows:

Table 2.1 Dates when surveyors (I-IV) carried out surveys at the replicate sites

Date	Site RA	Site RB	Site RC	Site RD	Site RE	Site RG
18/07/02	I	II	I	II	I	II
24/07/02	II	III	II	III	II	III
08/08/02	IV	I	IV	I	IV	I
12/08/02	III	IV	III	IV	III	IV

The four surveyors had varying levels of experience.

The sites are coded consecutively from downstream up. RA, RB and RC are all downstream of a small ford on Beck Lane, Smardale, a single-track road with little traffic. There are abundant trees and shrubs on both banks, the adjacent pastures being fully fenced. RB is used by reared ducks, which have access from an adjacent field to an area of shallow sloping bank and the stream itself. RD, RE and RG are upstream of the ford. The stream passes through two pastures grazed by cattle and sheep. The stream banks are unfenced. There is no site RF because it is a 100m length of shallow bedrock and step cascades, with little searchable habitat. It was considered to be too different from the other sites to be included as a replicate site.

The aim was to space the surveys out approximately a week apart to allow time for crayfish to settle themselves after each survey. Surveyors replaced the stones searched as close to their original position as practicable during the replicate sessions. As in the main survey, all crayfish caught were released to refuges in the patch in which they were captured.

The actual dates of survey were adjusted as necessary to allow for suitable flow conditions. Weather conditions are always variable in Cumbria, but July and August 2002 were wetter than average. Conditions for the surveys were slightly poorer on 24/07/02 and 12/08/02, as the water was clear but brown-coloured after a period of rain in previous days. Water levels and velocity were slightly higher than on the other two days, but conditions were still suitable for surveying.

2.3.3 Stretches surveyed on Scandal Beck

The purpose of surveying the stretches was to determine the distribution and abundance of crayfish in Scandal Beck and to survey enough sites and stretches to estimate the variability within sites, between sites and between stretches. In most of the stretches it was clear that there was abundant habitat and that 100m was a sufficient length of site. In the some of the stretches at the downstream end of the watercourse some sites of 200m length were included to see whether there was any significant difference between these and 100m length sites.

In all, 10 stretches were surveyed on Scandal Beck that had previously been surveyed using River Habitat Survey (RHS). Each 500m stretch was sub-divided into 100m lengths. A total of 31no. 100m sites and 4no. 200m sites were surveyed. The four 200m sites were all in the stretches closest to the confluence with the River Eden. Each was paired with a 100m site in the same stretch for comparison. In the rest of Scandal Beck, 100m sites were used. Sites are identified using the RHS reference number. A letter code is added, A-E from the downstream end of the stretch. The grid reference was recorded at the downstream end of each site using a hand-held GPS. The sites are shown on Figure 1.1 at the end of the report.

2.3.4 Stretches surveyed on River Lowther

The purpose of surveying the stretches on the Lowther was the same as on Scandal Beck, but in this much larger river, the emphasis was on testing the limits of conditions for survey and the site length required. On the River Lowther sites of 100m and 200m length were paired in every stretch, generally a 100m site first, followed by a 200m site.

On the River Lowther, 10 of the previously surveyed RHS sections within the SSSI were surveyed. In each 500m section two or three sites were recorded, in general a 100m and a

200m site for comparison. The total number of sites surveyed was 23. The sites are shown on Figure 1.2 at the end of the report.

2.3.5 Fixed area sampling

In recent years, some studies in the UK and elsewhere have included manual searches of all potential refuges on a defined area of riverbed. These are labour-intensive, but are the nearest estimates to the actual population density in specific, small areas. A limited amount of sampling in quadrats was undertaken in Scandal Beck, to allow comparisons between the standard survey method and fixed area estimates of density.

Quadrats 1x1m were recorded as follows:

- Smardale Gill NNR (22718A) on 10/7/02 (unenclosed quadrats)
- replicate sites RB and RD on 17/8/02 (with fine plastic mesh enclosures).

2.4. Method of Analysis

The data from the surveys are classified by the following:

- Stretch (usually a 500m RHS section)
- Site (within stretch, 100m or 200m long)
- Patch (within site, the area in which 2 lots of 5 refuges are selected)
- Order (1st or 2nd 5 refuges in patch)
- Day
- Surveyor

Each observation consists of crayfish counts from 5 refuges.
The counts have a Poisson distribution, with the log of the mean being modelled as linear in the above effects, i.e.

$$count_{ijklmn} \sim Poisson(\mu_{ijklmn})$$
$$\log(\mu_{ijklmn}) = mean + \alpha_i + \beta_j + \chi_k + \delta_l + \varepsilon_m + \phi_n$$

Here α_i is the effect of the i^{th} stretch etc. All effects are assumed to be random, i.e. there is a component of variance due to each effect:

$$\alpha_i \sim N\left(0, \sigma^2_{stretch}\right)$$
$$\beta_j \sim N\left(0, \sigma^2_{site}\right)$$
$$\chi_k \sim N\left(0, \sigma^2_{patch}\right)$$
$$\delta_l \sim N\left(0, \sigma^2_{order}\right)$$
$$\varepsilon_m \sim N\left(0, \sigma^2_{day}\right)$$
$$\phi_n \sim N\left(0, \sigma^2_{surveyor}\right)$$

The mean and all variances are given vague prior distributions.

Interest is always in the variance components, i.e. how much of the variability in the counts is due to the various classifications.

The number of crayfish seen is recorded for each patch and as a total. Relative abundance is expressed as the average number of crayfish per 10 refuges. This is given for individual sites and can be calculated for the monitoring unit or surveyed reach overall. Population abundance was also graded using the 5-point scale in Table 2.2.

Table 2.2 Average counts of crayfish and grading of population abundance

Ave. no./ 10 refuges	**Population abundance**
>5	Very high
>=3, <=5	High
>=1, <3	Moderate
>0, <1	Low
0	Absent or undetected

3. RESULTS AND DISCUSSION

3.1 Replicate Trial Results

The results from the replicate sessions are shown in Table 3.1. This is the total number of crayfish recorded from 50 refuges at each site on different occasions. The average abundance per 10 refuges is shown in parentheses.

The total number of crayfish recorded by individual surveyors in a session of three sites ranged from 204 to 401. The abundance of crayfish recorded at individual sites ranged from 3.8 to 18.8 /10 refuges.

Table 3.1 Total number of crayfish per site from replicate surveys and average abundance (ave. no. / 10 refuges)

Date	Surveyor	RA	RB	RC	RD	RE	RG	total
18/07/02	I	58 (11.6)		39 (7.8)		71 (14.2)		**168**
18/07/02	II		48 (9.6)		57 (11.4)		54 (10.8)	**159**
24/07/02	II	38 (7.6)		34 (6.8)		49 (9.8)		**121**
24/07/02	III		46 (9.2)		47 (9.4)		40 (8.0)	**133**
08/08/02	IV	22 (4.4)		19 (3.8)		39 (7.8)		**80**
08/08/02	I		76 (15.2)		63 (12.6)		94 (18.8)	**233**
12/08/02	III	28 (5.6)		33 (6.6)		36 (7.2)		**97**
12/08/02	IV		43 (8.6)		30 (6.0)		51 (10.2)	**124**
	Total	**146**	**213**	**125**	**197**	**195**	**239**	**1115**

3.1.1 Analysis of variance for replicate sites

The mean counts per 5 refuges are as shown in Table 3.2 below. The mean count per 5 stones allows the order effect to be included as a component in the analysis, i.e. which 5 refuges are sampled first and second in a habitat patch. Note that mean counts per 5 refuges are used for the analyses in order to determine whether there is any significant difference when 5 or 10 stones are searched, i.e. the order effect.

Table 3.2 Replicate surveys, mean counts per 5 stones

	Site					
Day	1 (RA)	2 (RB)	3 (RC)	4 (RD)	5 (RE)	6 (RG)
1	5.8	4.8	3.9	5.7	7.1	5.4
2	3.8	4.6	3.4	4.7	4.9	4.0
3	2.2	7.6	1.9	6.3	3.9	9.4
4	2.8	4.3	3.3	3.0	3.6	5.1

The model used is as described in the methods in 2.4 above, except that there is of course no stretch effect. The results of the analysis of variance are shown in Table 3.3.

Table 3.3 Replicate surveys, components of variance

Factor	Posterior medians of the variances
Surveyor	0.17
Day	0.01
Site	0.09
Patch	0.11
Order	0.00

The results in Table 3.3 can be summarised as follows:

1. Differences between surveyors make the largest contribution to the variance.
2. The day effect is very small.
3. The order effect is almost zero. This means that there is no change (on average) from the first 5 refuges to the second 5.
4. The patch and site effects are rather large.

3.2 Discussion of the Replicate Trial

3.2.1 Surveyor effect

The surveyor effect is not surprising, since the four surveyors had very different levels of experience. This effect was particularly large due to one very high count from the most experienced surveyor and one low count from the first survey of the least experienced surveyor (IV). Surveyor IV had little prior experience of crayfish. She took part in the training and then carried out two replicate sessions a month later. Surveyor I varied his approach to sampling during his second session, aiming for the highest possible counts by being extremely selective over individual refuges. His total on 8/8/02 included an exceptional find of crayfish in site RG. A total of 24 crayfish was found by dismantling a single broken section of bedrock only about 0.5m across. When surveyor I was working with surveyors II and III, the totals per patch were similar to those of the other surveyors.

It is likely that in a baseline survey or monitoring the surveyor effect would be smaller, since the surveyors would all be experienced. Also they would usually be working in pairs for safety reasons. Nevertheless, some training and practice in the technique is necessary to reduce the variability.

3.2.2 Patch effect

The large patch effect would suggest that it is worth taking as many patches as possible in a site. The experience of the trial showed that it was sometimes difficult to find more than five reasonable patches to search. For practical reasons therefore taking five patches per site is the recommended strategy.

During the replicate trial surveyors took extra care to replace refuges right way up and as much as possible in the same position, albeit pebble and cobble from beneath boulders could

not be fully re-instated in position. It was clear from careful inspection on site and discussion among surveyors that everyone recognised favourable patches and in areas with less abundant habitat tended to search the same areas.

3.2.3 Order effect

The negligible order effect means that taking 10 refuges rather than 5 makes very little difference to the outcome, compared to doubling the sample size in any other way (e.g. taking twice the number of patches or sites). The extra cost is minimal, and the experience of the trial is that there is no disadvantage in taking 10 rather than 5, so searching 10 refuges per patch is recommended. It is likely to be much more important to search 10 refuges at sites with less abundant populations.

3.2.4 Site effect

The site effect is compared with the patch effect in the analysis of results from the rest of the sites on Scandal Beck and the River Lowther. Nonetheless, looking at site effect alone, Table 3.4 shows the replicate sites ranked in descending order of crayfish abundance, as recorded by individual surveyors and overall.

Table 6.4 Ranking of replicate sites according to total crayfish recorded

Surveyor and site rank by highest count				Site ranking
I	**II**	**III**	**IV**	**total no.**
G	D	D	G	G (239)
B	G	B	B	B (213)
E	E	G	E	D (197)
D	B	E	D	E (195)
A	A	C	A	A (146)
C	C	A	C	C (125)

All the surveyors recorded their lowest counts of crayfish in sites RA and RC. Both of these sites had a steeper bed gradient overall, with a much greater proportion of fast-flowing riffle or shallow run. Although all the surveyors were able to find five patches they thought were worth searching, there was much less choice than in the other replicate sites. For example, in RC everyone searched at least one patch in a shallow area of marginal deadwater on a cobble and boulder sidebar among butterbur (*Petasites alba*). In sites upstream of the ford, all the surveyors concentrated on the extensive and highly favourable glide habitats, omitting the margins of riffles.

During one of the replicate sessions, on 12/08/02 there was a minor pollution incident when someone appeared to wash out a muck spreader on the ford between sites RC and RD, which caused a small slick of slurry to run down the stream. One surveyor previously recorded in RC “a lot of thick algae on stones in this backwater downstream of the road ford”. This was probably due to mild enrichment from mud on the road, or other use of the ford for washing farm machinery.

3.3 Results from Site Surveys on Scandal Beck

In all, 41 sites were surveyed on Scandal Beck, excluding the repeat sessions in the replicate trial. Figure 3.1 shows the total number of crayfish recorded at each site according to distance from the confluence of Scandal Beck with the River Eden. Only white-clawed crayfish were found. The lowest numbers of crayfish are recorded at the downstream and upstream ends of Scandal Beck. Sites between 2km and 7km upstream of the confluence show varied counts of crayfish, but the total number is greater than 25 at all sites. The abundance at all these sites is more than 5 crayfish per 10 refuges. The same dataset is shown on Figure 3.2. The sites from left to right are at increasing distance from the confluence. Here they are shown with the average count of crayfish per 10 refuges, (i.e. the average number per habitat patch).

The lower abundance of crayfish at the upstream end is very clear. From site 22721E the abundance is less than 1 crayfish per10 refuges, except at 22723E, where it is 1.2/10 refuges. At three consecutive 100m sites there were no crayfish recorded at all.

At the downstream end the two stretches nearest the confluence had crayfish present at every site, but only at one of the 5 sites did the abundance exceed 5 per 10 refuges.

Overall, omitting the repeated sites from the replicate trial, the average abundance of crayfish in Scandal Beck is 4.75/ 10 refuges $\pm$ 1.1 (95% confidence limits, no. sites 41). If the sites from 2272D upstream are excluded, the average abundance is 6.53/ 10 refuges $\pm$ 1.03.

Figure 3.1 Total number of crayfish recorded per 50 refuges in Scandal Beck, sites in order from Eden confluence

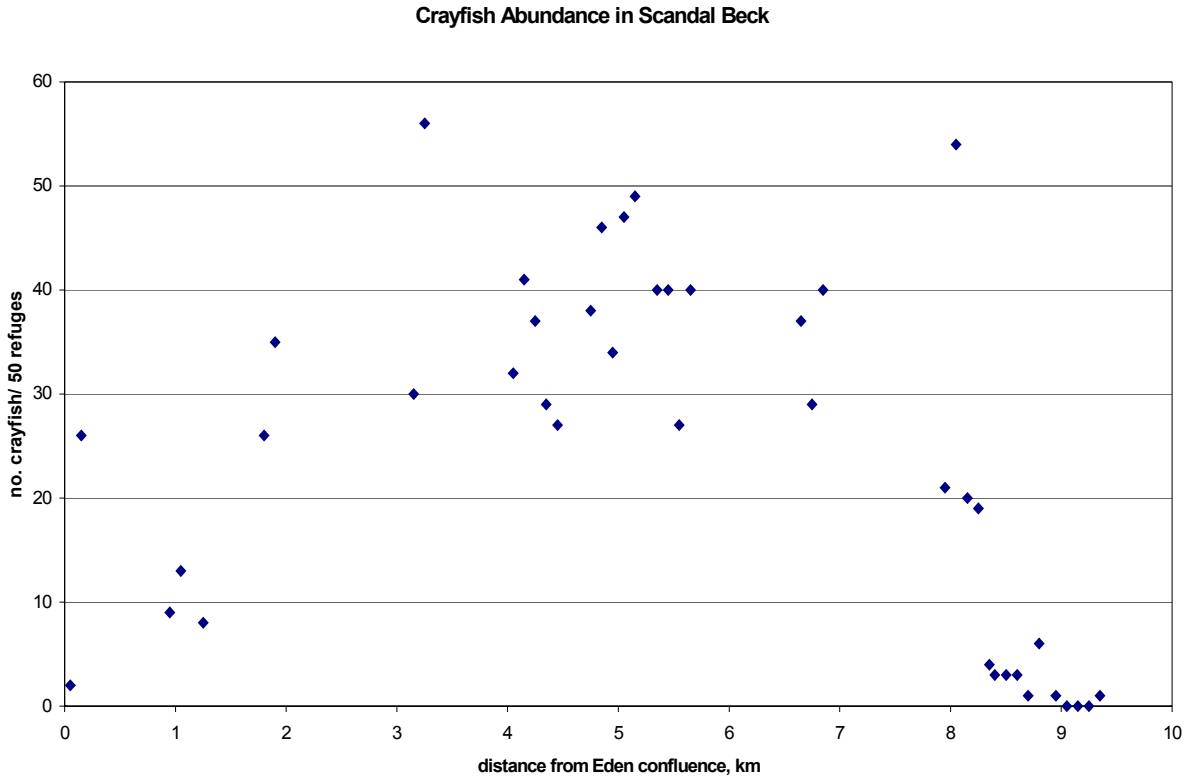
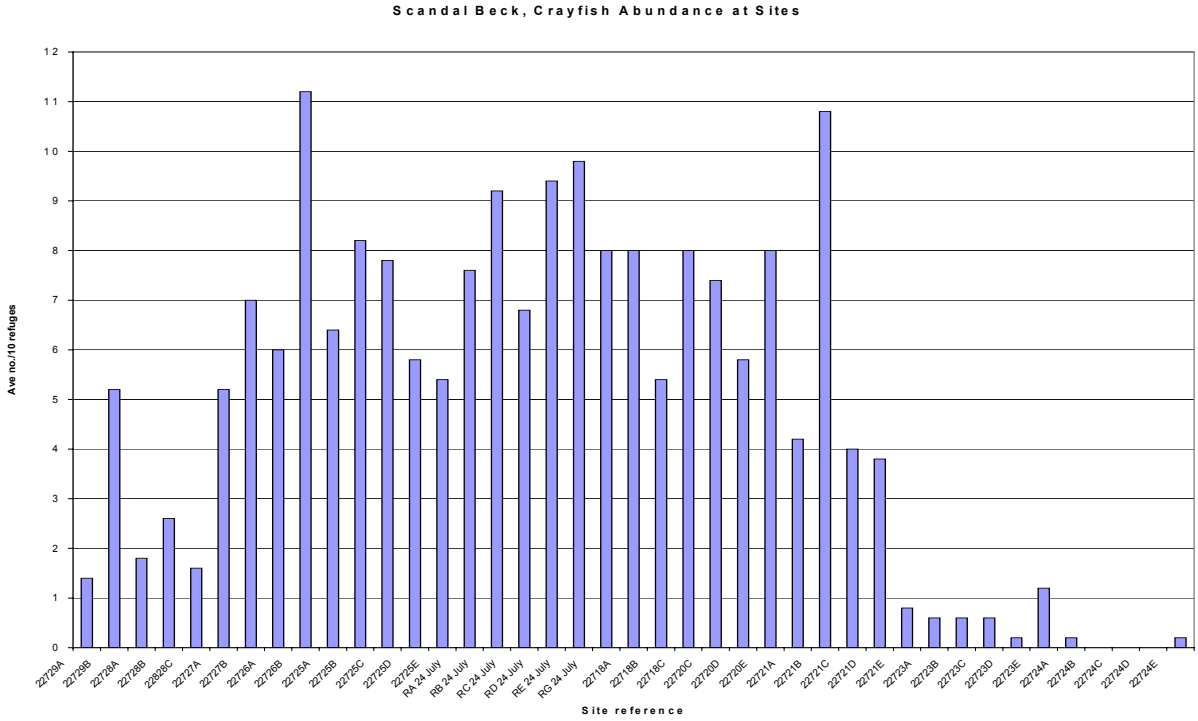


Figure 3.2 Average number of crayfish per 10 refuges at sites on Scandal Beck



3.4 Analysis of Variance for Scandal Beck

A total of 11 stretches were sampled, with 2 to 6 sites within each. The 6 site stretch formed the replicate trial as described above. The mean counts per 5 refuges for each site were analysed, using the same method as was used in the replicate trial. The sample results are given in Table 3.5 and the results of the analysis in Table 3.6.

Table 3.5 Scandal Beck, mean counts per 5 refuges

Stretch	Mean counts per 5 refuges at each site in stretch					
1	0.3	2.6				
2	0.9	1.3	0.8			
3	2.6	3.5				
4	3.0	5.6				
5	3.2	4.1	3.9	2.9	2.7	
6	5.75	4.1	4.45	3.3	5.8	4.5
7	4.0	2.7	4.0			
8	3.6	2.9	4.0			
9	2.1	5.4	2.0	1.9	0.4	
10	0.3	0.3	0.3	0.1	0.6	
11	0.1	0	0	0	0	0.1

Apart from the replicates, all the sites were surveyed by two surveyors, almost always the same two. These were therefore counted as a fifth surveyor in the modelling. The order effect (i.e. which refuges were searched first) was omitted, as it again was shown to be negligible.

Table 3.6 Scandal Beck surveys, components of variance for all sites

Factor	Posterior medians of the variances
Day	0.05
Stretch	2.15
Site	0.14
Patch	0.05
Surveyor	0.18

The very large stretch effect was due to approximately 25% of the sites having very low counts, compared to very high counts in the others (stretches 9 and 10 and the last site in stretch 8). It is suspected that this is due to a pollution event. If these sites are omitted from the analysis the results are as shown in Table 3.7. The stretch and site components are reduced. The stretch and surveyor components are the biggest effects.

Table 3.7 Scandal Beck surveys, components of variance of unpolluted sites

Factor	Posterior medians of the variances
Day	0.04
Stretch	0.20
Site	0.08
Patch	0.05
Surveyor	0.24

The results of the full analysis of the Scandal Beck survey can be summarised as follows:

1. The biggest effect by far is the difference between stretches. This effect is still larger than all the others apart from the surveyor, even when the analysis is restricted to sites with high counts.
2. The surveyor effect is large, based on the replicates experiment that is incorporated in this analysis. As discussed, the surveyor effect in the replicate trial is larger than is likely to occur during the surveys.
3. The day effect is larger than in the replicates experiment. However, this effect is partially confounded with the stretch effect (i.e. different stretches were surveyed on different days). Taking into account the replicate trial therefore, it is likely that the day effect is in fact smaller, and the stretch effect even larger.
4. The patch effect is not negligible, confirming that as many as practical should be surveyed. The experience again shows, however, that 5 is the practical limit of what can be sampled at most sites on a stream of this type.
5. The site effect is quite large, but small compared to the difference between stretches.

3.5 Discussion of Habitat and Survey Limitations at the Downstream End of Scandal Beck

3.5.1 Burrows in banks

Above the confluence with the River Eden (site 22729A), Scandal Beck is mainly a fast flowing, shallow riffle and run. The substrate is mainly pebble and small cobble, with beds of water crowfoot (*Ranunculus* sp.). There is relatively little stone in the channel large enough to offer refuges. The surveyors ran out of material in the channel considered to be worth searching. Only 3 crayfish were found using the standard method. In addition, the surveyors had a short session looking for refuges in the banks. The banks were shallowly undercut along most of their length on both sides, with overhanging grass. One additional crayfish was found by pulling two partly detached lumps of sandy clay from the eroding banks. Further crayfish were found in burrows. The technique was to work a hand, without gloves, deep in to wholly or partly submerged crayfish burrows, feel for a crayfish, work away the substrate around the animal and gently pull it out. Probing nine burrows yielded three crayfish, all adult females. More than a third of the burrows may have been occupied, but sometimes it was necessary to give up searching a burrow, due to the presence of buried stone. Crayfish obtained by searching refuges in banks were not aggregated into the total count for the site. Details were recorded on the survey sheets.

3.5.2 Access limitations and poor weather

Site 22729B was much more typical of in-channel habitat in Scandal Beck and had 5.2 crayfish/10 refuges. The downstream part of the site was inaccessible due to depth and some of the patches had a lot of bedded stone or silt accumulating in the margins of deep glides or pools. This was a site where there was more potentially suitable habitat than was accessible for surveying.

During the survey of 22729B weather conditions started to deteriorate, as rain set in and flow started to increase. It was possible to complete the survey of 22729B satisfactorily, but no further survey work could be done that day, or for several days afterwards. The rest of the surveys on Scandal Beck were carried out in good conditions, as surveys were postponed if weather forecasts were unfavourable.

3.5.3 Crayfish present, but possibly fewer than expected

In stretch 22728 the three sites surveyed are mainly in unfenced pasture, with quite a lot of erosion in places and several informal fords used by livestock and farm vehicles. In addition, there is a lot of small cobble the channel and areas with fairly fast flow. The most favourable areas are undoubtedly in the banks, especially where stone and rubble has been tipped to provide protection against scouring. Places where there was slightly undercut bank had plenty of scope for burrows, although the substrate was too stony to search the burrows effectively.

There were some further limitations – a long pool too deep to survey, a 50m length of unbroken bedrock at the upstream end of 22728C, plus some areas of marginal deadwater in glides where a combination of deep layers of stone and deposited silt made conditions difficult. Nonetheless, even where conditions were ideal for survey, the count of crayfish was relatively low. For example in 22728C there was a glide with lots of loose boulder scattered over sand and some pebbles. Clarity was good. There was loose moss and leaf litter

collecting under stones, but little or no silt, yet only one crayfish was found in each of two patches. That glide was immediately downstream of a ford on the access road to a farm, so it is possible that local water quality was limiting, rather than habitat.

3.6 Discussion of the Sites Affected by Pollution

Downstream of Ravenstonedale, sites 22724E to 22721A form an almost continuous series of 15 sites. There is a break of less than 100m between 22721E and 22723A. A total of at least 13 of these sites are believed to be affected by past pollution. Potential refuge habitat is abundant. There is no difference between the types of patches available in these sites and those in Smardale Gill NNR (22720, 22718) and the replicate sites (RA-RG), where there is very high abundance of crayfish. These sites and the intervening lengths of stream down into Smardale Gill were inspected to see if there were any features that might constitute a barrier to the movement of crayfish, for example a small waterfall, or a ford with an overhanging lip. There were no barriers and the limestone stream is sensibly the same throughout, albeit with plenty of variation within sites.

Pollution seemed to be the most likely reason for the very low abundance of crayfish. The rest of the invertebrate fauna appeared to be characteristic of the beck, with no sign of reduced water quality, suggesting that the pollution problem was a past, rather than current episode.

Possible sources were considered. Outside the study area in the lower part of Ravenstonedale village, there are obvious signs of nutrient enrichment, abundant growth of filamentous algae, although this disappears outside the village. Downstream of the A685 bypass there is a small, village sewage works. A brief inspection was carried out in the stream adjacent to the sewage works. Only 30 refuges were searched in the time available, in an area with a lot of bedrock, but 8 crayfish were found (average 2.3 per 10 refuges), much higher than any of the sites in 22724 or 22723.

Further downstream there is a farm just before the top end of site 22724E and it is possible that this was the source of pollution at some time in the past.

The nature of the pollution and when it occurred are not certain. It seems to have eliminated or severely reduced the crayfish populations for about 1.5km or more, although crayfish were found at low abundance this year. There is a recovery zone around Smardale Bridge. **The time required for full recovery is not known, but it is likely to take several years after the end of the pollution problem for crayfish to recolonise and increase to the abundance found elsewhere in Scandal Beck.**

3.7 Analysis of the Catch in Scandal Beck

3.7.1 Size distribution

A total of 1937 crayfish was recorded from Scandal Beck using the standard method, although 28% of these evaded capture. Figure 3.3 shows the recorded size distribution for captured males and females. Slightly more females were recorded than males, 53% female and 47% male. The distribution is multi-modal, reflecting the age classes. Crayfish of 10mm carapace length (CL) or less are not shown here, as sex was not always determined in small crayfish. The data have not been analysed in detail, but the difference in modal peaks for males and females are evident in the distribution of the larger sizes. This is related to the reduced period for growth available to breeding females.

The overall size distribution is shown in Figure 3.4. For most of the survey period the young of the year were still attached to the females, or too small to catch effectively. The modal peak at 11mm represents 1+ animals. The other size classes are less distinct because growth rates vary markedly between individuals, leading to considerable overlap in year classes.

Figure 3.3 Size distribution of crayfish from Scandal Beck by sex

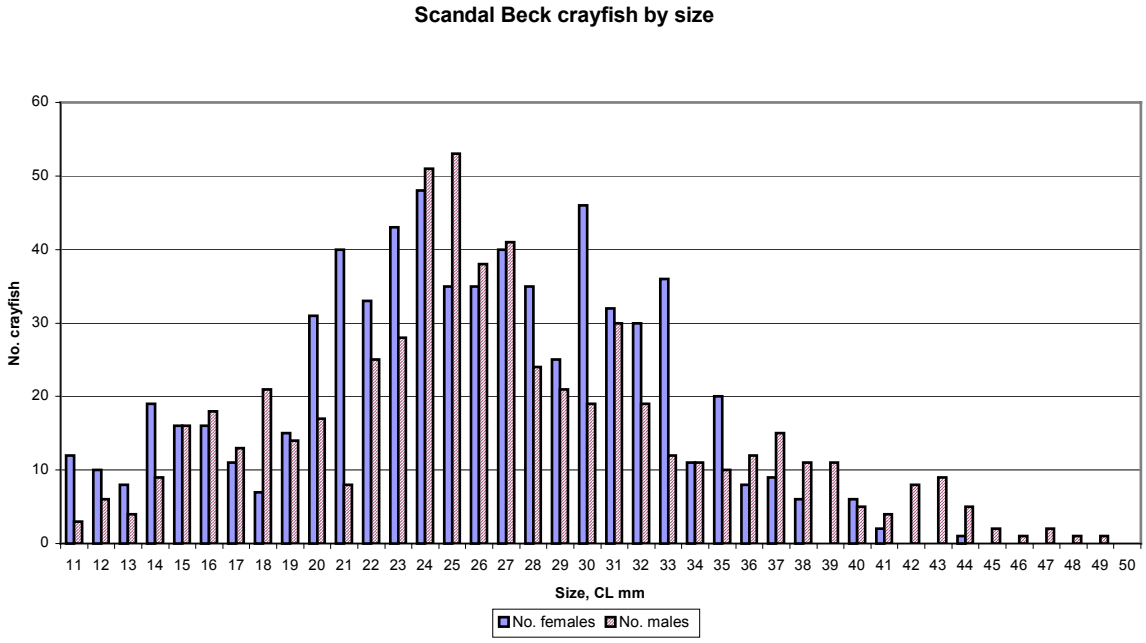
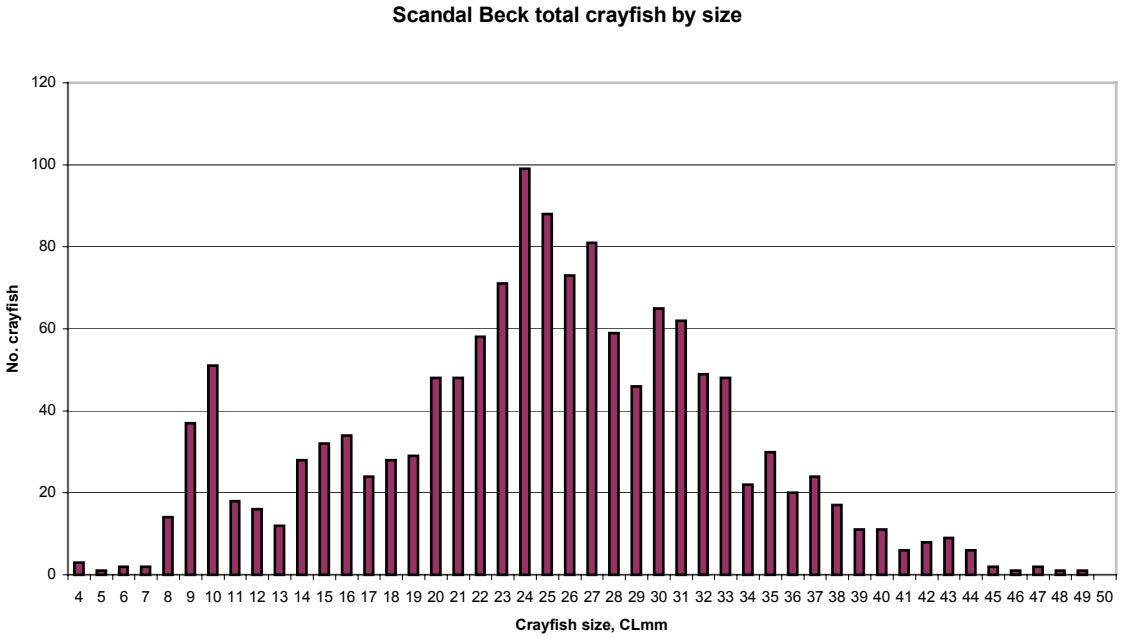


Figure 3.4 Overall size distribution of crayfish in Scandal Beck



3.7.2 Breeding and proportion of juveniles in the population

The cooler conditions in Cumbria mean that white-clawed crayfish carry their young later in to the summer than those further south. Figure 3.5 shows only the data for the replicate sites arranged by date with the proportion of adult females carrying young, or having bred, as evidenced by the presence of glair strands. These attachments for the eggs and young are lost once the crayfish have moulted. The chart shows only the proportion actually undergoing or recovering from moulting at the time of capture. 24th July was the latest date when females were found carrying young. The proportion of females with glair strands declined during August, as the crayfish went through a moult, but the strands could still be found on some females as late as 22nd August (the end of the survey period).

Figure 3.6 shows the proportion of females either with young or glair strands in the survey period according to their size. The smallest female found with young was 22mm CL. At 25mm CL the proportion recorded as breeding was 20%. This is an underestimate of the actual proportion breeding, because females that moulted prior to capture are not recorded as having bred. By 30mm CL, over 80% of females were recorded as having bred and the actual proportion is likely to be close to 100%. Considering the size distribution, it appears that in this northern river growth is relatively slow and females do not have their first brood until aged three years or more.

Figure 3.5 Breeding stage of females by date.

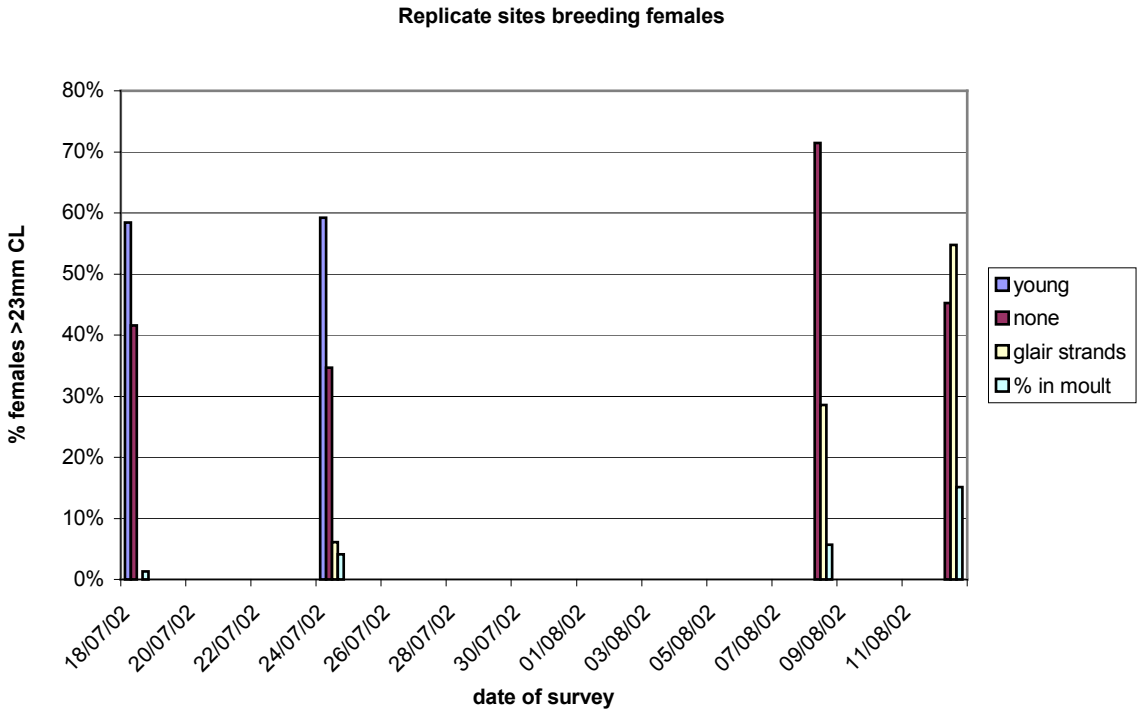
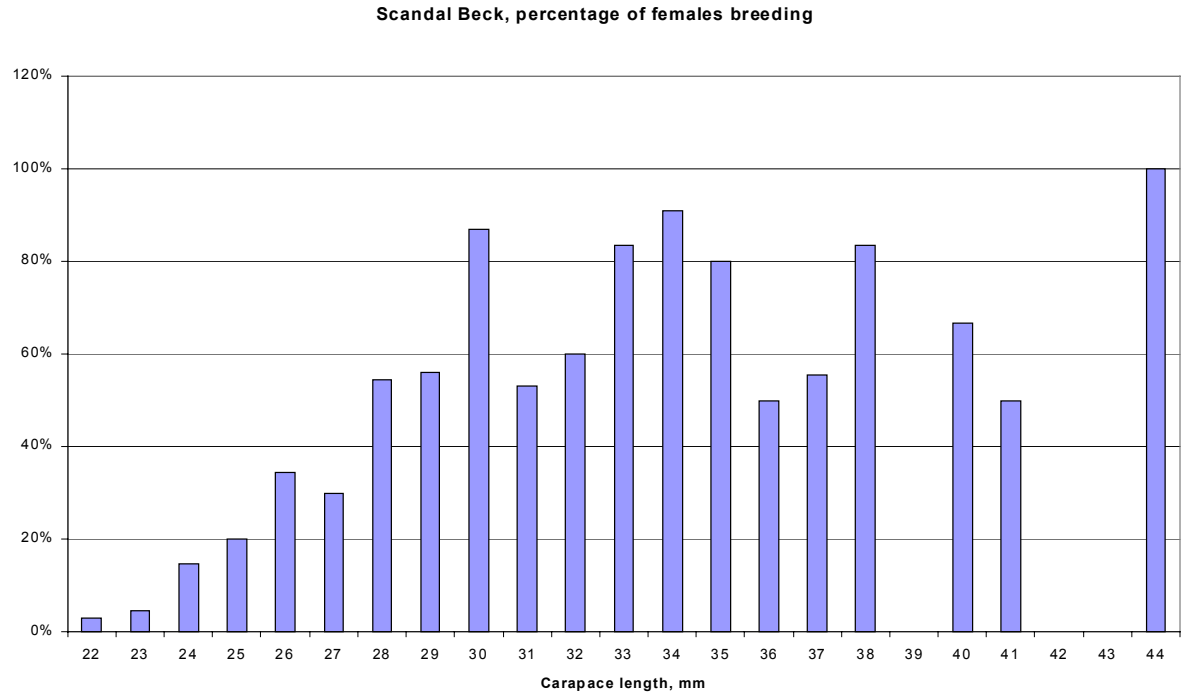


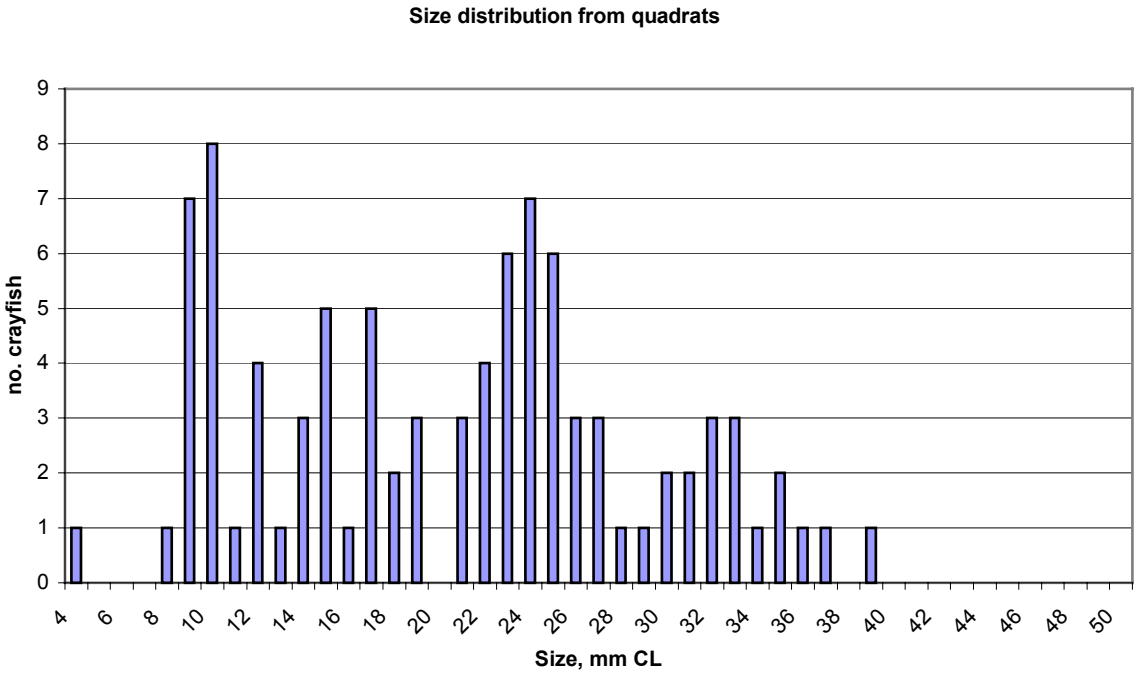
Figure 3.6 Percentage of females recorded as breeding



A size of 25mm CL is commonly used as a division point between adults and juveniles, although as indicated by Figure 3.6, it is a transition rather than a sharp division. The proportion of crayfish below 25mm CL was 46.5%. The surveyors' records of juvenile and adult escapes gives a similar figure of 45%. The proportion of juveniles recorded using the standard method is an underestimate of the actual proportion of juveniles in the population.

The main reason for the size bias is that surveyors select the potential refuges they think are likely to be most favourable for crayfish. As the larger animals can commandeer the preferred refuges, this leads to a size bias in the sample. For comparison, Figure 3.7 shows the size distribution for crayfish caught during fixed area sampling of 1x1 quadrats. The smaller sample size affects the distribution. Nonetheless, the proportion of juveniles less than 25mm CL is 67%, significantly higher than the 46.5% using the standard method.

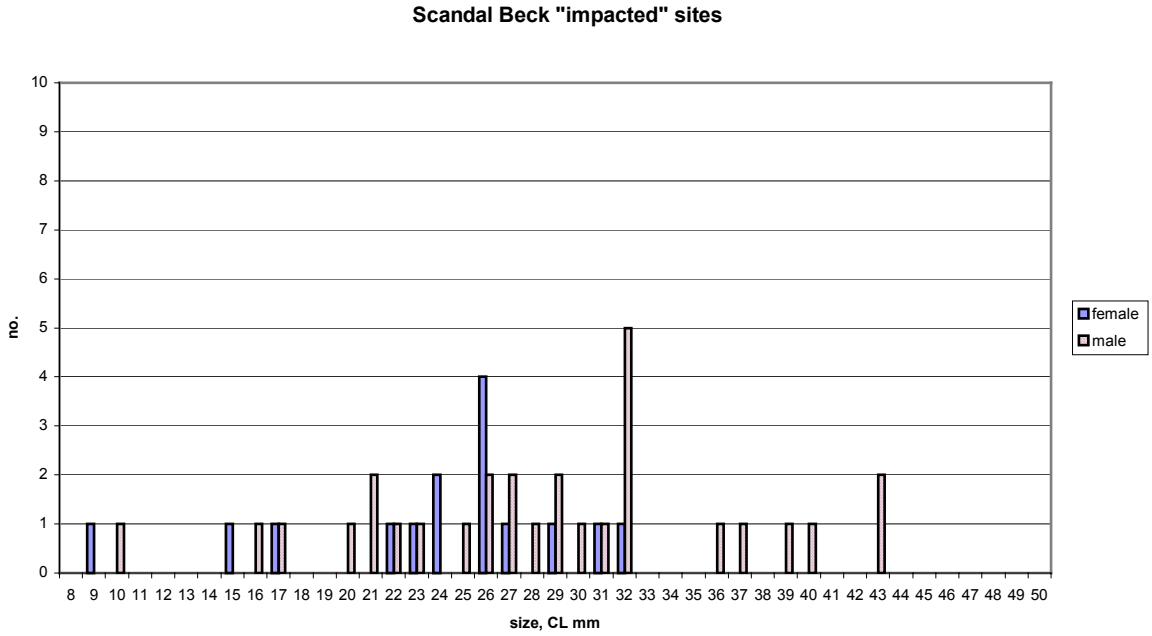
Figure 3.7 Size distribution of crayfish recorded from quadrats



3.7.3 Size distribution in the area affected by pollution

The sites thought to have been affected by pollution had few crayfish and the size distribution is therefore patchy, as shown in Figure 3.8. The proportion of juveniles is lower than for Scandal Beck as a whole, 31% compared to 46.5%. The sex ratio is also skewed, with 65% males. Of the 8 females 25mm CL and above, only one was breeding and this was found, in the "recovery" area downstream, (i.e. 12.5% breeding). Impacted sites were surveyed on 12th and 15th July. By contrast, unaffected sites surveyed on 15th and 16th July had 80% of female breeding at size 25mm CL or more. From this it appears that the breeding females lag behind males in the recolonisation of sites affected by pollution.

Figure 3.8 Size distribution at impacted sites on Scandal Beck



3.7.4 Health of the population

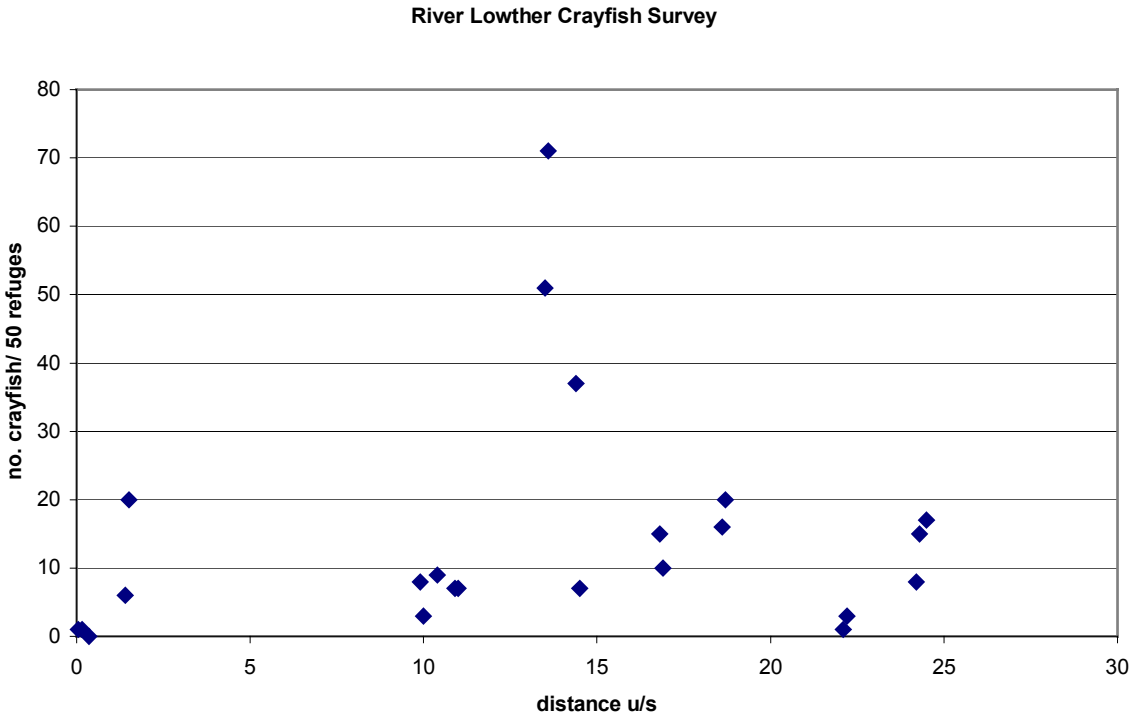
Incidence of disease and damage were recorded. Thelohaniasis or porcelain disease occurred at only 3% and incidence of burnspot disease was 2%. Porcelain disease eventually causes mortality in affected individuals. It varies considerably in white-clawed crayfish populations, but populations with less than 10% occurrence of the disease are considered to be in good health.

In all, 8% of crayfish had a missing or regenerating cheliped (large front claw), usually an indication that crayfish have been in competition with other individuals. The proportion of damage was similar in male and females.

3.8 Results from Site Surveys on River Lowther

The results from the survey on the Lowther are shown in Figure 3.9 as total number of crayfish per site (i.e. per 50 refuges). Crayfish were recorded at all sites from below the confluence with the River Eamont to the upland area between Wet Sleddale Reservoir and Shap, further upstream than any previous records on the Lowther. The abundance at sites range from 0.2 to 14.2 crayfish / 10 refuges. The average abundance for the sites sampled was 2.90 $\pm$ 1.48 (95% confidence limits, 23 no. sites).

Figure 3.9 Total number of crayfish recorded per 50 refuges in River Lowther, sites in order from below Eamont confluence



On the River Lowther 23 sites were surveyed in 10 stretches by one pair of surveyors, with an additional surveyor at half of the sites. In order to test the effect of using a 200m site each stretch was divided into one site of 100m and one of 200m (except for stretch 5 where it was impossible to get 5 patches in any 100m stretch). Stretches 1, 3 and 10 also had an extra site. The site lengths were as shown in Table 3.8.

Table 3.8 River Lowther stretches and sampling sites

RHS section	Stretch	Length of sites in stretch, m	Mean counts per 5 stones		
22821	1	100, 100, 200	0.1	0.1	0.0
22822	2	100, 200	0.6	2.0	
22825	3	100, 200, 100	0.8	0.3	0.9
22826	4	100, 200	0.7	0.7	
22828	5	200, 200	5.1	7.1	
22875	6	100, 200	3.7	0.7	
22876	7	100, 200	1.5	1.0	
22877	8	100, 200	1.6	2.0	
22850	9	100, 200	0.1	0.3	
22829	10	100, 200, 200	0.8	1.5	1.7

The model used for the analysis is as described for Scandal Beck, except that a factor for the length was included and two levels (100m and 200m). Surveyor was omitted because the same two surveyors were always used, even when there was an additional surveyor present. Also omitted was the day effect because it was confounded with stretch, and the previous

experiments suggest that the day effect is negligible. The analysis of variance is shown in Table 3.9.

Table 3.9 River Lowther surveys, components of variance for all sites

Factor	Posterior medians of the variances
Stretch	0.35
Site	0.08
Patch	0.1

The means for the two different lengths are 100m 1.15 and 200m 0.95. These are not significantly different.

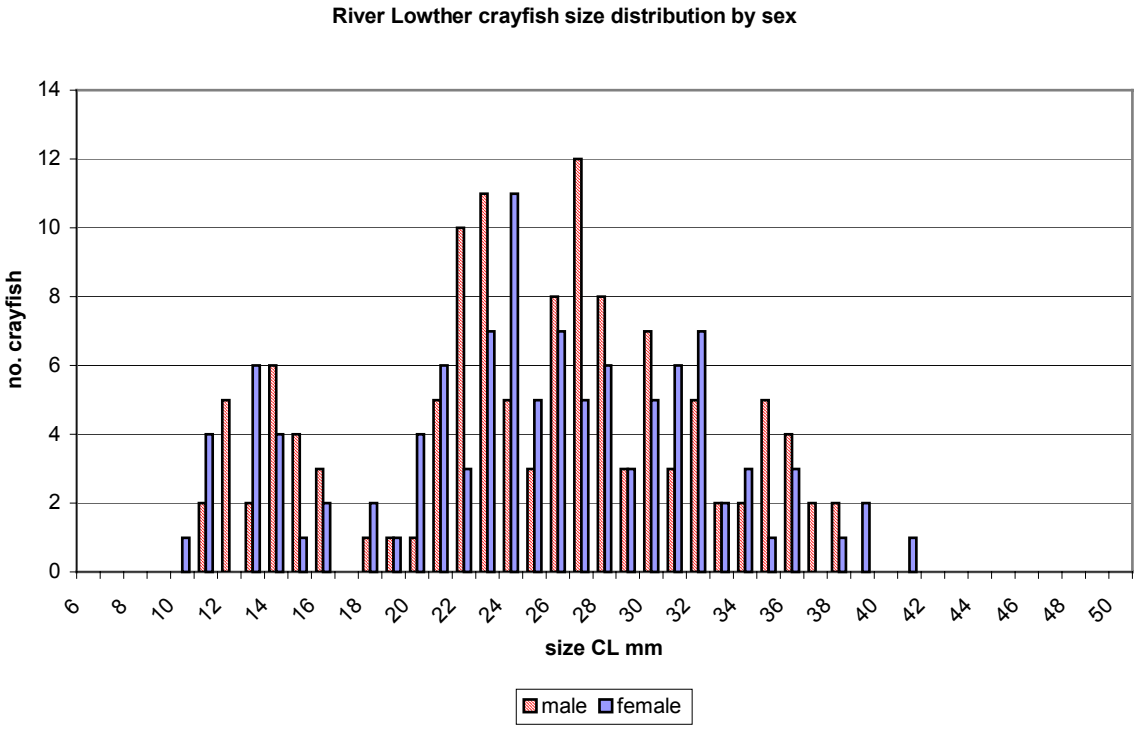
In conclusion:

1. The stretch and patch components of variance are larger than those in Scandal Beck because the Lowther is a more variable river.
2. The stretch effect is again by far the largest. Hence a sampling strategy should cover as many stretches as possible rather than sampling two or more sites per stretch.
3. The length effect is negligible. Using a 200m site instead of a 100m one in a larger river does not introduce any bias.

3.9 Analysis of the Catch in River Lowther

The total catch from the Lowther was 231 crayfish, plus a further 101 escapes (30%). Females represented 47% of the catch and males 52%. Juvenile crayfish below 25mm CL represent 47% of the catch, the same as in Scandal Beck. The population was also in good health, with only 2% incidence of porcelain disease.

Figure 3.10 Size distribution on River Lowther



3.10 Discussion of the Lowther Survey

3.10.1 Crayfish in a stream in upland pasture

The River Lowther is much more varied than Scandal Beck. Sites at the upstream end (22829 upstream of Shap and 22850 at Keld) were in hill pasture, with the stream banks cut vertically through peat in places. The adjacent vegetation is mainly acidic marshy grassland, dominated by soft rush (*Juncus effusus*). In the slower flowing areas, the stony bed is covered in a thin layer of peat silt. The river is clearly subject to scouring spates, although this seems to be reduced to a degree by the reservoir upstream. This initially seems an unlikely place for crayfish, but the acidity of the adjacent land is buffered by the presence of underlying limestone in the catchment. The stream also receives drainage from the settlement ponds of a limestone quarry near Shap.

3.10.2 Inaccessible areas of the big river

At the downstream end of the Lowther at Eamont Bridge and elsewhere on this large river, parts of the channel were too deep to survey or wade. In much of the middle reaches this confined the survey to the margins of one bank. Most of the river has a cobble and boulder bed. This meant that sufficient patches and refuges could usually be found within a 100m site, although there were some problems where the channel was sand or gravel with few accessible boulders. Several 10's metres of a site might be unsuitable for survey in the large river, so 200m sites were sometimes needed, even though all the selected patches might lie in 50-100m of channel within the 200m site.

Where surveyors could get into the water, they could almost always find some crayfish in the selected patches. When the water level in the river was a little higher after a period of rain, there were some sites where there were good potential refuges in glides that became too deep to work and where accessible stone in marginal deadwater had too much silt to search effectively.

3.10.3 Effects of weather and flow conditions

Weather conditions were poor in the Lowther catchment for part of August 2002. A number of survey days had to be postponed, because even when the weather was dry, the river level stayed up for a while. Intermittent bad weather adds to the survey cost. Unless they live locally, surveyors have to make more journeys to and from the study area, rather than being able to carry out several consecutive days work from a temporary local base.

In general, survey was only carried out in good conditions. Nonetheless, it was decided to test the limits of the survey method. **Surveyors always used viewing boxes, made from a wooden drawer with the bottom replaced by a clear plastic sheet. This design has major advantages over the use of clear-bottomed plastic buckets, because the drawer floats without tipping over, it gives a much greater field of view than a bucket and can be used to hold crayfish.** As the inside surface of the box was wetted to improve viewing, light rain or drizzle made no difference to survey efficiency, as long as there was no increase in the flow or decrease in clarity. Surveying became more difficult if rain was breaking the surface sufficiently to make it harder to spot patches from a distance. In addition, surveyors tire more quickly in bad weather and so may be less effective.

On two occasions, surveys were carried out during slowly increasing flow. Crayfish could still be found, but individual animals seemed to be taking avoiding action, as they were often partly buried beneath the refuge, or tightly wedged between two pebbles or cobbles beneath a boulder. Some animals may have been too deep in burrows in the sand and gravel under stones to be detected. Clearing all stone to sand and gravel level is important in any survey, but especially in these conditions.

Some surveys were carried out when flow was receding, but the river was still strongly brown-stained due to runoff from peat in the upper catchment. Surveys can be carried out in coloured water, but there is sometimes a degree of cloudiness as well. The two factors make it harder to search in the deeper areas. It is still quite effective, provided a viewing box is used, although there may be poorer viewing at depths of 0.4m or more.

The conclusion is that surveys are best conducted in good weather and at moderate to low flows. Surveys should never be carried out during heavy rain or increasing flow.

3.10.4 High occupancy of refuges by crayfish

I

Interestingly, the stretch with the highest counts of crayfish, 22828 at Knipe Common, was also one of the two stretches with seemingly the least number of refuges. The river crosses a floodplain and the substrate is predominantly sand, gravel and pebble, with locally abundant water crowfoot (*Ranunculus spp*.). There are few large cobbles and boulders. The survey showed that in general, each stone of 20cm or more was used by a crayfish, unless it was too rounded or deeply bedded. Crayfish were also found under boulder-sized lumps of clay that had fallen from the banks. Almost all of the accessible refuges were searched. If these were

the only refuges in the channel, the recorded abundance of crayfish might be expected to be a lot lower. The key factor is the riverbanks. The low banks are cut vertically through sandy clay, with abundant overhanging rushes and their roots, plus other marginal vegetation along most of the length of the sites on both sides of the river. These banks are very good for crayfish burrows, albeit most were not obvious until vegetation was moved aside. The population in the banks is likely to be high, with crayfish moving out to fill up all of the limited number of favourable refuges in the channel.

The survey method includes an evaluation of each site, so surveyors give a qualitative estimate of the extent of potential habitat in mid channel, margins and banks. In the draft survey form this included a component of how accessible the site was. **The revised version has modified the categories and now includes "surveyability". This, plus additional notes made by surveyors, will help to distinguish between sites where there is abundant crayfish habitat, but not much of it is accessible for survey, and sites that are easy to access, but there is not much searchable refuge habitat.**

3.10.5 Is the Lowther different from Scandal Beck?

High counts of crayfish were found in parts of the River Lowther, but the average abundance of crayfish is lower on the Lowther than Scandal Beck (2.9 compared to 4.7 crayfish/ 10 refuges). The difference is not statistically significant, however.

As yet, there is not enough semi-quantitative data from different rivers to know what is typical of populations in different types of watercourse and this will take time and survey effort to acquire. Scandal Beck, where not affected by pollution, is likely to be among the best watercourses in the country in terms of abundance of white-clawed crayfish (average 6.5 /10 refuges)**.** There are likely to be other streams in Cumbria of similar quality.

The River Lowther is a much bigger river, 15-20m or more in width, compared to 5-10m on Scandal Beck. Whilst the relative abundance of crayfish may not be as great, the size of the channel in the Lowther means there is a great deal of potentially favourable habitat, only a proportion of which is accessible for survey. It might have a similar total number of crayfish, but with the population more dispersed.

There were more limitations on surveying in the Lowther. Nonetheless, there were occasions when surveyors were searching potentially very good habitat in favourable conditions for survey, but finding lower than "expected" numbers compared to similar habitat in Scandal Beck.

Local Environment Agency staff said there had been some water quality problems in the Lowther at times, although quality is now considered to be good and improving. It may be that parts of the Lowther population are in a recovery phase after intermittent pollution in the catchment, but these is no clear evidence for this.

Spates are a major issue for crayfish, determining the selection of refuges in these energetic watercourses. If avoiding predators were the only consideration, any stone big enough to cover a crayfish would be adequate. Instead it is very clear from the survey in these rivers and in others in northern England that the crayfish select big, stable refuges with good crevices and they also like the banks. The catchment size of the Lowther means it has more

flow than Scandal Beck, though both have peat uplands overlying limestone. Nonetheless, floods on the Lowther are generally much less than they would be in an unmodified catchment of the same size. The river is regulated from Haweswater and to a lesser degree from Wet Sleddale Reservoir. Stream energy may still be a factor, however. The stretch of the Lowther where the highest abundance of crayfish was recorded also had a low channel gradient compared to most of the other stretches. An increase in water level of less than 1m in the stretch would allow the Lowther to start spreading out over the floodplain.

Salmon, brown trout and eel were all seen in Scandal Beck, together with abundant bullhead and stone loach, but the diversity and abundance of fish is likely to be greater in the Lowther than in Scandal Beck. It is possible that this could be a factor, although it is probably not a major one.

In conclusion, the River Lowther is different from Scandal Beck. The crayfish do not appear to be as abundant, although the difference has not been shown to be significant. We do not know yet whether what is seen in the Lowther is typical of a river of this type.

3.11 Fixed Area Sampling

3.11.1 Results from quadrats

A limited amount of fixed-area sampling was undertaken using 1x1m quadrats in Scandal Beck. This was to provide an indication of population density in patches compared to using the standard method. The quadrats were only positioned in habitat that was considered to be favourable for crayfish. The estimates cannot be used to derive any average density for the stream. Results are summarised in Table 3.10.

During the training session the patch counts may be over-estimates, as there was a group of 9 people training in the method and practicing finding crayfish. In some instances the search of stone underlying the selected refuges was more extensive than that undertaken in a standard survey. The survey of site 22718A undertaken by the two main surveyors is more representative of the abundance of the site.

Some of the quadrats recorded during the training session were placed in patches where crayfish had been found and released earlier in the day. The degree of disturbance may have produced lower density estimates. The quadrats located in measured cross-sections had not previously been surveyed. Despite this, there is a significant difference between the quadrats in patches and those randomly selected from those parts of a transect across the channel that could be surveyed. This does seem to indicate that surveyors can recognise the most favourable habitat to survey.

Table 3.10 Fixed area sampling compared to patch counts using standard method

Site reference	**Quadrat type**	**Details**	**No. Quadrats**	**Ave. no. crayfish /m2** (95%CL)	**Range in no. per quadrat**
22718A training session	1 x 1m unenclosed	In patches surveyed by standard method 1-2hr earlier, (4 surveyors in 2 groups)	2 in each of 3 patches	7 ±3.75	2-13
22718A training session	1 x1m unenclosed	Randomly located cross-section divide into 1m2, random selection from "surveyable" metres (4 surveyors jointly)	1 in each of 3 transects	2.3 ± 1.4	2-3
RB	1 x1m enclosed by mesh	1 quadrat in 1 possible/actual patch, 2 in another. Details of refuges recorded. Pool used heavily by reared ducks	3	3.3 ±1.4	3-4
RD	1 x1m enclosed by mesh	Details of refuges recorded. Located in glide along RB margins upstream of footbridge	5	11.0 ±6.2	6-19
Site reference	**Standard method**	**Details**	**No. patches**	**Ave.no crayfish/ 10 refuges**	**Range in no. per patch**
22718A	Yes, but more practice/ demo	9 people on training session, some searches extended beyond individual refuges.	5	18.4±9.8	8-28
22718A	Yes	2 surveyors, main survey	5	8.0±4.7	3-13
RB	Yes	Replicate sessions, 4 different surveyor on 4 dates	5	10.0±2.6	3-26
RD	Yes	Replicate sessions, 4 different surveyor on 4 dates	5	10.0±2.0	3-20

Quadrats in RB gave a density of 3.3±1.4 crayfish m^{-2} (95%CL), compared to those in RD where the density was 11.0+6.2 crayfish m^{-2}. This is at least partly due to habitat, as there were more large cobbles and boulders in RD than in RB at the quadrat locations. It is also possible that the heavy use by ducks in part of RB has a localised impact via disturbance, predation or water quality.

The counts per 10 refuges for the RB and RD sites as a whole are not directly comparable with the quadrats, because 5 different patches were surveyed in each 100m site. Each patch in these sites typically covered in the order of 2-10 m^2. Both fixed area sampling and the relative abundance method show that crayfish are abundant in Scandal Beck.

In RB and RD an attempt was made to compare quadrats and the standard method more directly. Results are shown in Table 3.11. At lower density, selecting the most "favourable" refuges increases the chances of detecting crayfish. At high density of crayfish, many individuals are missed within each $1m^2$, but the search strategy leads to a high count when 10 selected refuges are searched.

Table 3.11 Evaluation of refuge potential within quadrats in Scandal Beck

Site and quadrat ref (1x1m)	**No. Boulders (25-40 cm) in quadrat B**		**Large Cobble (15-25cm) LC**		**Small Cobble (6-15cm) SC**		**No. cray-fish /m2**	**No. and type of refuge that would be chosen if this area was within a patch surveyed using the standard method.**
	+	-	+	-	+	-		
RB 1	**0**	0	**3**	4	**0**	43	**4**	2 LC. (2 crayfish)
RB 2	**2**	1	**1**	8	**0**	42	**3**	2 B, max 5 stones. (2-3 crayfish)
RB 3	**2**	2	**1**	8	**0**	21	**3**	3 B, 0-2 LC. (1-3 crayfish)
RD 1	**2**	2	**4**	5	**1**	15?	**12**	3 B. (4-6 crayfish)
RD 2	**5**	0	**6**	3	**0**	20	**19**	3 B. (3-8 crayfish)
RD 3	**1**	2	**2**	3	**3**	19	**10**	3 B, poss. 2 LC. (3-6 crayfish)
RD 4	**1**	3	**3**	10	**3**	22	**8**	3 B. (1-2 crayfish)
RD 5	**1**	3	**3**	6	**1**	24	**6**	2B. (1 crayfish)
(+:number of stones with crayfish present, -: number of stones without crayfish)								
Note: the number of stones with crayfish does not necessarily equal the total number in the quadrat, as boulder or large cobbles sometimes have 2-3 crayfish. Also the refuge initially used by a crayfish is sometimes uncertain (1 crayfish in RD 1 and 4, 6 crayfish in RD 2). RD 1-5 progress upstream, and the proportion of loose stone decreases. Counts of cobble and boulder in these quadrats include some partly bedded stone that would not be searched in standard method.								

3.12 Standard Survey Method, Limits of Detection

The author carried out an unrelated project on Long Preston Beck, in Ribblesdale in Yorkshire, a limestone stream similar to some of the tributaries of the River Eden. A standard survey was carried out in a 100m site that had a glide in the top 20m or so of the site. There was a steeper section downstream, with abundant cobble and boulder, but faster flowing. Most of the left bank was steep, more than 3m high and actively eroding. The overall survey result for the site was 0.8 crayfish/10 refuges, a low abundance. Additional refuges were searched, to take the search to 50 refuges in the glide and 50 in the run/riffle section. The result for the glide was 1.2 crayfish/10 refuges and 0 for the rest of the section.

Works were planned to stablise the stream bank, using large stone blocks. An area of streambed of about $70m^2$ was cleared of all cobble and boulder along the left margin. White-

clawed crayfish were removed and relocated in the glide upstream. The material was saved for use in re-instatement of the channel. In the $9m^2$ of the glide that was cleared, the density was 0.5 crayfish m^{-2}. In the run/riffle, 10 crayfish were recorded from a total of $60m^2$, a density of 0.17 crayfish m^{-2}. In the run/riffle, the crayfish tended to be found under the largest stones and in the deeper areas, where cobble was lying several stones deep and was consequently difficult to search effectively during a standard search.

These results suggest the lower limit of detection of the standard survey method is a density somewhere in the range 0.17 to 0.5 crayfish m^{-2} and is probably towards the lower end of the range. Populations at or below 0.2 crayfish m^{-2} may be viable, even if they are not consistently detectable.

At low abundance, crayfish may be missed altogether. For example, in the length of Scandal Beck affected by pollution, there were 10 sites that had less than 1 crayfish/10 refuges and crayfish were not recorded at 3 sites, although they may have been present. The lowest abundance that can be recorded in a standard survey is 0.2 crayfish/10 refuges, i.e. finding 1 crayfish from 50 potential refuges.

The probability of finding at least one crayfish from a search of 50 refuges where the true abundance is 0.02 (1 from 50 refuges) is 0.63. The actual abundance has to fall below 0.014 (1 crayfish in 71 refuges) before there is less than 50% chance of finding at least one crayfish. The lowest abundance at which there is a high chance of detection, say 90%, is 0.046 (approximately 1 crayfish from 22 refuges).

This is just for a single site. If ten sites are sampled in a monitoring unit that has a low abundance of crayfish throughout, the chance of failing to detect crayfish is ten times less. If the average abundance is low, but in a few places it is high, then the probability of detecting crayfish is the same as the probability of finding a good site. Provided there are areas of river within the monitoring unit that can be surveyed, there is a high probability that surveyors using the survey method will find crayfish, even when the population is at low abundance.

3.13 Recording Other Species and Habitat

The survey method is designed for crayfish. Given the need to concentrate on the selection of habitat patches and individual refuges, it is not practicable to survey for other purposes at the same time. Ad hoc observations of signs of otter, mink or water vole could be noted by surveyors, but would not be the basis of any monitoring for these mammals.

The crayfish survey requires the recording of some of the same features that are recorded in River Habitat Survey. Crayfish surveyors need to be able to recognise a few basic flow types, but the rest is fairly obvious on the survey forms. The recording is at the level of the habitat patch, only a few square metres in extent. RHS survey is carried out at a much coarser scale and it would be difficult for any surveyor to do both at the same time. **RHS survey cannot be undertaken concurrently with crayfish survey.**

Because of the difference in scale, RHS is not a very good predictor of whether crayfish will be present. It should not be assumed that crayfish are absent on the basis of a RHS. There were only a few sites surveyed in 2002 for which the RHS model (Naura & Robinson, 1997)

predicted crayfish would be absent, on the basis of information from previous RHS habitat surveys. Crayfish were found at all of them.

The only species besides crayfish that was recorded as part of the method was another Biodiversity Action Plan species, the bullhead (*Cottus gobio*). The presence of bullhead was noted in each patch. With surveyors counting the number of crayfish caught and missed from the first and second five refuges in each patch, it was not feasible to count the number of bullheads seen at the same time. Only presence was recorded. It would need on surveyor searching and one simultaneously recording in order to fully record crayfish and bullhead.

There is a considerable overlap in the habitat used by the two species. For both the optimum habitat in the Eden tributaries was a slow-flowing glide, with abundant loose boulder and large cobble. Bullheads were at notably lower abundance in the higher energy sites, where there were extensive riffles or runs. In favourable habitat, white-clawed crayfish and bullheads were often found occupying the same refuges.

4 CONCLUSIONS FROM FIELD-TESTING IN THE EDEN TRIBUTARIES

4.1 Survey Method

1. **The survey method is effective for identifying the presence of crayfish and their relative abundance at a range of population densities and in a range of habitat types** in the Eden catchment.
2. Taking 10 refuges in each of 5 patches per site is a practical approach. The number of refuges searched could be varied if required, but the minimum number of patches searched should be 5 at any site.
3. The site length can be varied when necessary. Using a 200m site instead of 100m in a larger river does not introduce any bias.
4. The difference between stretches (500m sections) is by far the most important effect. Therefore it is not necessary to sample more than one site per stretch, it is better to sample more stretches.
5. The effect of different surveyors with a wide range of experience was tested. It does affect results. The effect is reduced by:
   - using experienced surveyors trained in the use of the method,
   - allowing for a practice session at the start of every survey season and
   - ensuring that surveyors work in pair or groups of three.
6. The survey method is not sex-biased – approximately equal numbers of males and females were recorded in the summer survey period.
7. All sizes of crayfish are represented, although the 1+ and possibly 2+ are slightly under-represented. The 0+ crayfish were not recorded until the end of the survey in mid August, because in Cumbria the females were still carrying young in late July.

4.2 Condition of the Population

8. Most females do not breed until 25mm CL or more. Juvenile crayfish 1+ and above represented 47% of the catch in both rivers, using the standard method. Populations are breeding in both rivers, with no sign of any abnormal size distribution.
9. Incidence of disease is low in both tributaries, indicating healthy populations, porcelain disease was found in only about 2% of the catch.
10. No alien crayfish were found and none are known in the catchment.
11. White-clawed crayfish were found throughout the lengths of the River Lowther and Scandal Beck within the SSSI.
12. Crayfish were found at very high to high abundance in Scandal Beck and moderate to high abundance in River Lowther. The variability of the survey results means that the difference has not been shown to be significant.
13. The only section of Scandal Beck where crayfish were found at low abundance was downstream of where there may have been pollution from a farm. The rest of the invertebrate fauna appears to have recovered, but the crayfish population is thought to be recovering much more slowly.
14. Based on the attributes, measures and targets in the favourable conditions tables, Scandal Beck would be assessed as being in 'Favourable Condition' for white-clawed crayfish. The judgement of condition of crayfish has been made on abundance and recruitment, rather than dependent attributes from the favourable condition tables, which would also need including as part of the overall assessment of condition.
15. Approximately 1.5km of the SSSI, about 15% of the Scandal Beck monitoring unit is considered to be in unfavourable status due to pollution, but it is probably recovering. It may take a further 2-5 years for it all to recover to the abundance seen downstream in Smardale – assuming no further pollution incidents occur.
16. The rest of Scandal Beck is certainly in favourable status, with a high to very high abundance of crayfish, plenty of breeding occurring, a normal range of sizes and low incidence of disease.
17. **There is no national guidance on how much of a river needs to be in favourable condition to be classed as favourable overall. It is recommended here that at least 90% of a river should be in favourable status. On this basis Scandal Beck would be classed as being in unfavourable status, but recovering.**
18. **The River Lowther is assumed to be in favourable status, in the absence of any information about the expected abundance in large rivers in the Eden catchment.**

5. DEVELOPING A MONITORING STRATEGY FOR THE RIVER EDEN

5.1 How Many Stretches to Sample?

In order to assess the effect of different sampling intensities, we consider rivers 'similar to' the Lowther and Scandal Beck. Because the variation between stretches is greater than that between sites in the same stretch, there is no benefit in sampling more than one site per

stretch. The site counts for the two rivers were therefore "bootstrapped". This means sampling repeatedly from the sets of counts used in the analysis of results in section 3 above.

For a sampling intensity of two stretches in the Lowther, for example, we randomly select two stretches from the data, and one site within each stretch and record the counts. This is repeated 1000 times and the distribution of overall mean counts for the monitoring unit is recorded.

Histograms of these counts are shown in Figure 5.1, with Scandal Beck on the left and River Lowther on the right, and the number of stretches sampled increasing down the page. The histograms show the number of occasions in 1000 that different mean numbers of crayfish per 10 refuges are expected to be recorded, according to the number of sites sampled.

It can be seen how the distribution gets narrower, and closer to the true value (mean abundance of crayfish in the monitoring unit), as the number of stretches sampled increases.

The same model results are shown in Table 5.1. Here the classification of relative abundance is given, with results allocated a grade of abundance on a five-point scale from absent to very high abundance. Again it can be seen how the classifications get more consistent as the sampling size increases. Note, however, that both rivers are on the border between two classes: high and very high for the Scandal Beck, and moderate to high for the River Lowther. Taking only 1 sample site would mean that the Scandal Beck would be classed as having moderate abundance or less 33% of the time. This is because some stretches were affected by pollution. For 5% of the surveys, crayfish would go undetected. Increasing to at least 8 sample sites on Scandal Beck would reduce the chance of the same error in grading to 5% and crayfish would always be detected. Over-estimating the abundance classification will occur too. The River Lowther would be recorded as having a very high abundance of crayfish 7.6% of the time with 8 samples, when the actual grading would lie between moderate and high.

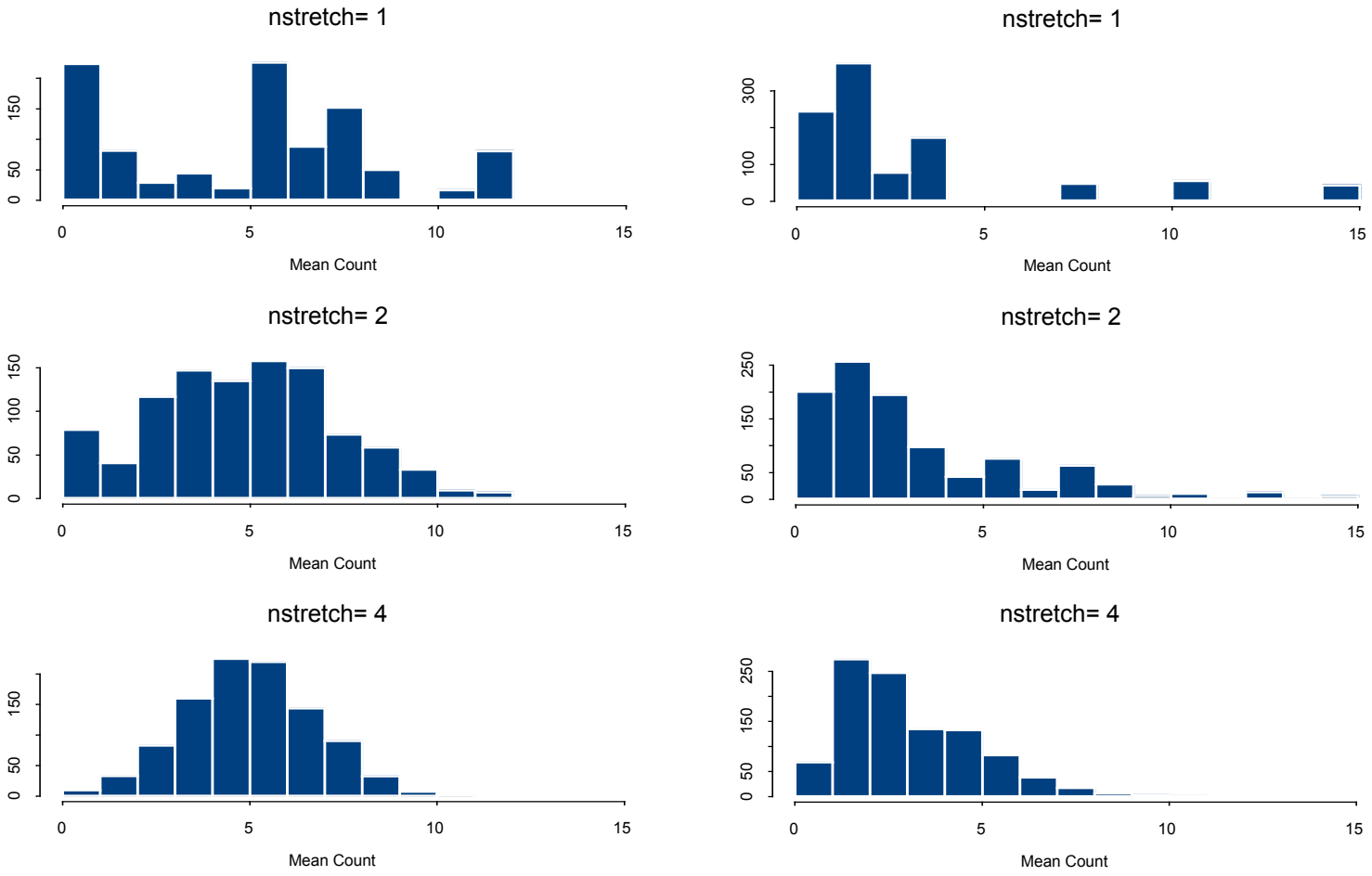
In a relatively homogenous river, what matters is the number of samples, not the proportion of the total length actually sampled or the distance between the sample sites. The 10 km length of Scandal Beck has similar variety of habitat throughout and could be classed as a single reach. The River Lowther differs in character along its length as the flow and stream energy vary along more than 25 km of river. It would probably be classed as more than one reach using the new method of classifying river reaches, which is currently in development by the Environment Agency. The Lowther is, however, a single site monitoring unit within the SSSI.

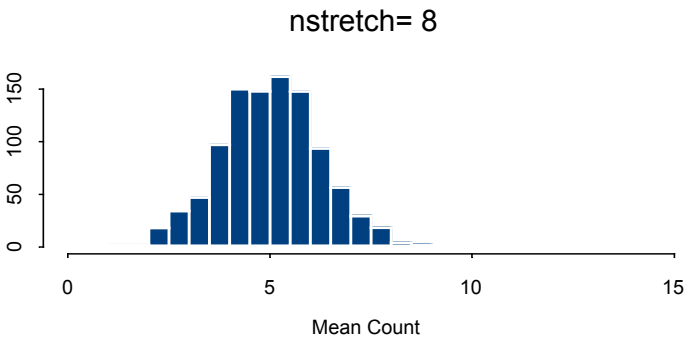
Table 5.1 Probability of population abundance classification for Scandal Beck and River Lowther

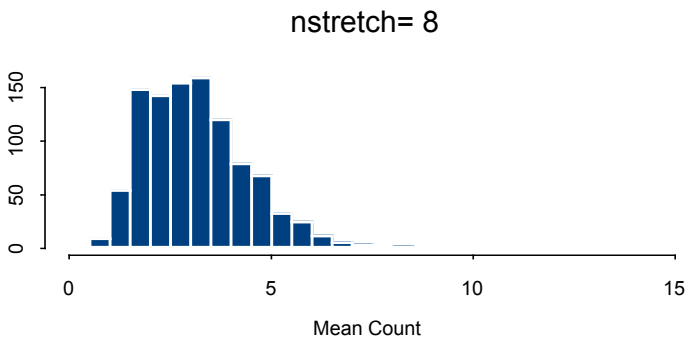
No. stretches sampled	**Percentage of stretches by grade of population abundance (mean no. crayfish/10 refuges)**				
a) Scandal Beck	**Absent or undetected (count 0)**	**Low (count <1)**	**Moderate (count 1-<3)**	**High (count 3-5)**	**Very high (count >5)**
1	5.1	17.1	10.8	6.2	60.8
2	0.5	7.3	15.6	28.0	48.6
4	0	0.9	11.4	38.3	49.4
8	0	0	5.2	43.8	51.0
16	0	0	1.1	48.8	50.1
32	0	0	0	49.2	50.8
No. stretches sampled	**Percentage of stretches by grade of population abundance (mean no. crayfish/10 refuges)**				
b) River Lowther	**Absent or undetected (count 0)**	**Low (count <1)**	**Moderate (count 1-<3)**	**High (count 3-5)**	**Very high (count >5)**
1	2.2	21.9	44.7	17.0	14.2
2	0	19.9	44.8	13.7	21.6
4	0	6.8	51.9	26.6	14.7
8	0	0.8	49.4	42.2	7.6
16	0	0.1	48.9	48.8	2.2
32	0	0	44.7	54.9	0.4

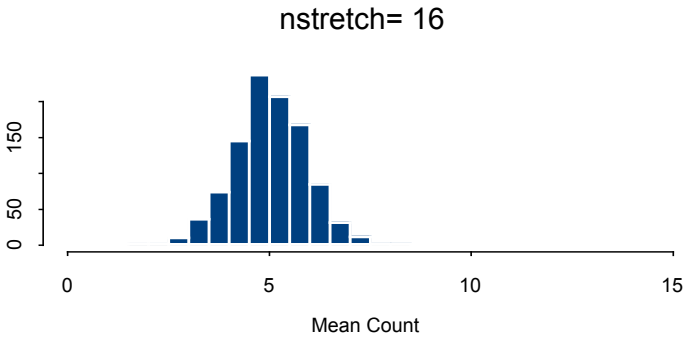
Figure 5.1 Simulated mean counts of crayfish/10 refuges in Scandal Beck and River Lowther

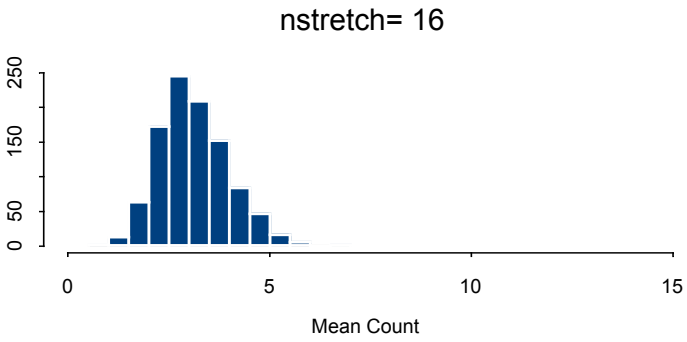
Scandal Beck **River Lowther**

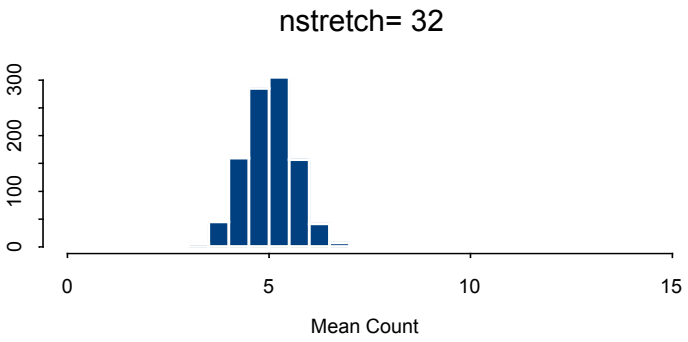


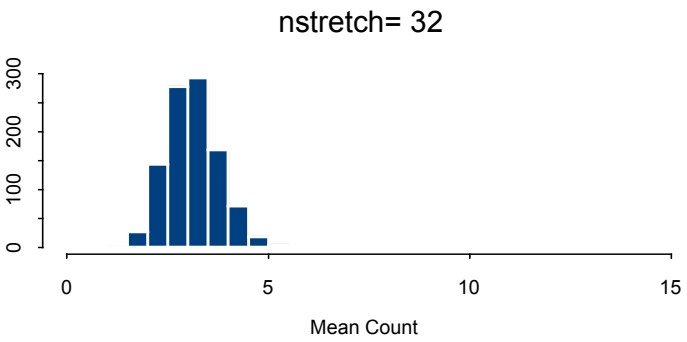

nstretch= 8
0
50
100
150
0
5
10
15
Mean Count


nstretch= 8
0
50
100
150
0
5
10
15
Mean Count


nstretch= 16
0
50
150
0
5
10
15
Mean Count


nstretch= 16
0
50
150
250
0
5
10
15
Mean Count


nstretch= 32
0
100
200
300
0
5
10
15
Mean Count


nstretch= 32
0
100
200
300
0
5
10
15
Mean Count

5.2 Recommended Monitoring Strategy

The recommendation for the River Eden is a best estimate based on the results of the field trial in summer 2002 and the analysis above. Once additional baseline survey has been carried out, better estimates can be obtained of the variation in different rivers.

5.2.1 General approach

1. The River Eden & Tributaries SSSI/SAC is divided into 36 site units for purposes of SSSI designation and monitoring. Of these, 15 are specifically designated for white-clawed crayfish and therefore require monitoring as part of the SAC reporting process. Two of these site units have been surveyed intensively in 2002. Some other tributaries of the Eden within the SSSI are known to have populations of white-clawed crayfish but are designated for other reasons. In other tributaries there has been little or no investigation and it is not known whether crayfish are present, although it is unlikely that any populations are present at high abundance.
2. **The priorities for monitoring are the tributaries designated for crayfish.** It is also important to know the geographic extent of crayfish within the catchment. Hence, it is recommended that at least some additional tributaries are surveyed using the standard method. This need not be carried out as part of the initial round of baseline survey, but. can be added later. This will improve understanding of the geographic range and abundance of the species locally and nationally.
3. **Manual survey can be used throughout the tributaries and most of the main river Eden, at least upstream of the River Eamont, although not necessarily at all sites.** In the Eden catchment there is ample habitat that can be searched manually and sites not feasible for manual survey can be omitted. Trapping is not required for monitoring the population in this catchment.
4. Manual surveys can be undertaken at any time during the growing season, but surveys after the breeding period are preferable. **In the Eden catchment, the recommended period for survey is the second half of July to the end of September.**
5. **It is recommended that the baseline survey should be completed within 3 years.** Alternatively, if resources are limited, the baseline survey may have to be spread out over 6 years, but if so, it is advisable to start monitoring at least some units 3 years after the baseline.

5.2.2 Selecting the stretches to be sampled

6. Select the sampling sites as follows: **randomly select the required number of 500m stretches of the monitoring unit to be surveyed or monitored**. In the Eden catchment, RHS sections can be used, but simply for convenience as there is, or is proposed to be, about 50% random coverage of the watercourses. Crayfish survey can and should be carried out independently of any RHS survey.
7. The number of samples depends on the accuracy required. **The current recommendation is at least 16 sample sites per tributary or monitoring unit for the baseline survey, on tributaries or units of 8km or more. There should be one site in each of the 500m stretches selected for survey. There should not be less than 8 samples for a baseline survey.**

8. There is no information available at present as to how homogenous the other monitoring units are with respect to habitat for crayfish. Scandal Beck is much the same along its 10km length, but the River Lowther varies more within the 25km surveyed. **If the reach or monitoring unit is fairly similar in the range of habitat along its length, it is the number of samples that is important, not how far apart they are.**

9. **Tributaries of all types that could potentially support crayfish should be surveyed, even those not currently known to support an abundant population of crayfish.** Crayfish can survive far up into the headwaters of upland catchments, provided there is some relatively base-rich rock present. The geographic limit is likely to be greater than existing records suggest. The River Belah, Crowdundle & Millburn Becks and Briggle Beck come from the steeper hillsides along the right bank of the River Eden. Surveys of these tributaries should not be restricted to the areas currently known to support crayfish.

5.2.3 Sampling sites

10. The surveyors start at the downstream end of the 500m stretch in the first 100m. If they think there are at least 5 suitable patches, they carry out the survey. If there are fewer than 5 patches, they can extend the survey to 200m. If the river cannot be surveyed in this area, they check and if possible survey the next 200m. If this is still cannot be surveyed, they carry out the evaluation of crayfish habitat in the 400m seen and go to another 500m section. Extra stretches should be selected in advance to replace any that are found to be unsuitable for survey.

5.2.4 Monitoring cycle

11. The reporting cycle for monitoring features of SACs is every 6 years; hence this is the maximum acceptable length of programme.

12. **It is recommended that the monitoring effort on any one tributary is divided between two years.** These need not be consecutive years, but it is national policy that any round of monitoring of a feature for which a SAC is notified must be completed within 3 years. **Dividing the monitoring of a watercourse between two years, or more, will help to average out the effects of weather and flow conditions and surveyors.**

13. Using the same suite of sites for monitoring each time is the quickest way of building up a dataset that can be considered over time, but it only records what happens at those particular sites. By chance, there will always be some sites that happened to be poor originally, or are affected by a change that may not be representative of what is happening in the river generally. **The recommendation is that on each monitoring occasion half the samples are previously surveyed sites and half are new ones.**

14. Suppose that 16 sites are surveyed in the initial baseline survey of a tributary or monitoring unit in year 1. Decide from the variability in these samples (and possibly other similar reaches or monitoring units) and the desired precision, how many samples to take in routine monitoring. If this is 8, then in the next monitoring cycle, take 4 sites from the baseline and 4 more. Survey 4 of the 8 sites in one year and 4 in the following year or the one after that. The extra sites should be new sites. In the

second cycle of monitoring take 4 different sites from the original sites, plus another 4 new sites. If desired, it would be acceptable to resurvey 8 sites from the original 16 in the first cycle, but in the second cycle of monitoring additional sites should certainly be introduced.

15. **The monitoring strategy should be reviewed and where necessary refined after 6 years.**

5.2.5 Find out more about variability

16. In addition, it is strongly recommended that **a series of tributaries/monitoring units is selected for investigation of variations over time, using a few sites. These should be surveyed annually for at least 5 years.** Types recommended for study in the River Eden and Tributaries SSSI include:
    - 1. a base-rich stream with high or very high abundance of crayfish;
    - 2. a relatively base-poor stream with naturally occurring moderate or low abundance of crayfish;
    - 3. a large limestone river.

    These will only be identified after the baseline survey.
17. For annual monitoring of an abundant population (type 1 in 16 above), the recommendation is to sample the replicate sites in Scandal Beck, or alternatively sites in 22718 in Smardale Gill NNR. At least one site should be monitored, but 4 or more is highly preferable to allow for analysis. This monitoring should be a separate exercise from any training/practice sessions undertaken at the start of the field season, to keep surveyor variability to a minimum.
18. **The sites and watercourses selected for annual monitoring to determine characteristic abundance and change over time should be chosen as being representative of a type, rather than because something unusual is happening there.**
19. At present, there is little information about the limits of crayfish populations in upland catchments. In some of these small streams, manual survey may be difficult. Intensive trapping may be of value for detecting the presence of crayfish at the extreme upstream limits of moorland catchments.
20. Fixed area sampling is too labour-intensive to be feasible for monitoring any extensive population of crayfish (see survey time in section 5.3.1). When used in conjunction with the recommended standard survey, it does enable comparisons to be made with other studies where fixed area sampling has been used. It is best used for additional studies at one or a few sites, not as part of the routine monitoring programme.
21. If using fixed area sampling it is best to work in sites where there is abundant favourable and "surveyable" habitat. Entirely randomly located quadrats at a site will show high variability, due to the patchiness of the distribution of crayfish. An alternative approach is to select a suitable habitat patch, as for a standard survey and place the quadrat in this. For example a patch might constitute 2 x 4m of glide with abundant boulder and large cobble. One or more randomly selected quadrat positions could then be located within the patch.

5.2.6 Targets

22. **Until more baseline survey is carried out, it is difficult to decide what the expected population abundance is in different types of watercourse.** This needs to be developed for watercourses in Cumbria and in other regions. **High quality streams similar to Scandal Beck can be expected to have populations averaging high or very abundance across a series of sample sites. Investigation is recommended if any individual sites change to having low abundance, as this may indicate a pollution incident.**
23. Results at individual sites can be expected to vary over time, but **it is not yet known how much the average abundance at all the sites in a monitoring unit will vary over time**. **Based on current knowledge, it is worth investigating any change in average abundance within a watercourse of one abundance grade or more.**
24. Monitoring crayfish populations during the recovery period after pollution is of local importance in the SSSI and of value nationally for estimating rates of recolonisation and population growth. At least one case study in the Eden catchment is recommended, e.g. downstream of Ravenstonedale. This should be considered as an additional monitoring requirement, rather than part of the national monitoring programme for SAC condition.

5.3 Resources Required

5.3.1 Survey time

A key consideration in any monitoring programme is how long will it take and how much will it cost. This depends on how the work is carried out. Table 5.2 gives an indication of the time required per sample.

Before surveyors get out on site work is required to select the 500m stretches, prepare maps and obtain permission for access. This is likely to require several man-days work prior to the start of the field season.

In addition, even surveyors who are experienced in the standard survey method should have one day familiarisation and practice together in the catchment at the start of the field survey programme each year. A replicate trial is also recommended using at least one site surveyed by all the surveyors individually. A site with moderate to high abundance of crayfish is preferable for the trial, rather than one with very high or low abundance.

Table 5.2 Time required per sample

Activity	Time, mins (total time of 2 surveyors)	Cumulative time, mins
Drive to site	Variable, assume 15 mins (30)	15
Park, organise gear, call at farm if required	Assume 5-15 mins (10-30)	20-30
Walk to site	Variable 1-60 mins, typically 10-15 (10-120)	25-90
Site survey including recording forms	Range 40-100 mins, actual average 70 mins (80-200)	65-190
Walk back	Variable 5-60 mins, typically 10-15 (10-120)	70-250
Remove waders, disinfect if required, load and leave	Assume 5-15 mins (10-20)	75-265
Total		Typical time per site assume c. 2 hours excluding drive to site (x 2 surveyors)

From arrival on the river bank at the start of a site to completion of survey forms takes 70 minutes on average, depending on the site conditions and abundance of crayfish. The time to prepare gear and walk to the site and back needs to be added to the survey time on site. This can easily double the time required.

Picking sites with easy access would possibly reduce the overall time, but it would also introduce unknown levels of bias and this would not be detected for years, if at all. The stretches and hence the sites need to be randomly selected. This is essential if sites are to be a representative sample of the reach or monitoring unit. Within sites, surveyors select "surveyable" habitat patches that seem to be most favourable for crayfish.

Three sites a day is a reasonable target for a team of two surveyors. Four sites may occasionally be achieved, but where access is lengthy or difficult only two sites may be the possible in a day.

Using three surveyors reduces the survey time, though not necessarily by as much as a third (2 surveyors do 2 patches each including recording, and 1 surveyor does 1 patch plus survey details, photographs etc.)

Fixed area sampling at sites in Scandal Beck took two surveyors 30-45 minutes per 1x1m quadrat. Five quadrats in site RG took two surveyors 3hours 45 minutes, about three times as long as a standard survey with two surveyors in this watercourse. This was sufficient to estimate the density in one habitat patch, but is not necessarily representative of site RG.

The variability of the weather in Cumbria means some days or part days will be lost due to unsuitable conditions (e.g. drizzle turns to heavy rain, or the weather is good, but the flow is still too high for effective survey). This increases the time spent travelling as sometimes surveyors will not find that conditions are unsuitable until they arrive at a site. **It is recommended that at least 10% contingency time is included in a survey programme for delaying survey days to periods with suitable conditions.**

The disinfection procedure is a standard requirement of crayfish survey licences to reduce the risk of crayfish plague. It takes 5-15 minutes to do, depending on the gear used on site. In the Eden catchment, with no alien crayfish or crayfish plague, the risks are very low indeed. Nonetheless, it is good practice to ensure that all equipment is disinfected or completely dried between surveys on different watercourses and definitely before and after any work outside the Eden catchment.

It is recommended that before entering Eden tributaries, for any purpose, all surveyors, not just those carrying out crayfish survey, should ensure all gear is clean and free from the risk of carrying crayfish plague. This is of paramount importance after any exposure in waterbodies outside the region that may have alien crayfish.

5.3.2 Data processing time

If surveyors use clipboards and paper forms, the data entry and checking, including referencing photographs, takes 0.75 to 2 hours per site, depending on the number of crayfish recorded and the speed of the operator. Surveyors should carry out, or at least check, all the data entry of survey forms themselves.

Data processing time may be reduced if surveyors are equipped with waterproof, hand-held computers with the spreadsheets pre-programmed and ready for use, but the equipment is expensive and takes time to set up.

Analysis of data and reporting requires additional time, generally more than is assumed and certainly several days per monitoring unit.

5.4 Analysis and Reporting

Recommendations for analysis of data are as follows:

- **Crayfish abundance per site** as No. crayfish/10 refuges **and average abundance per monitoring unit, with analysis of variance as described in the monitoring protocol.** There are no targets for crayfish abundance in different types of river as yet, but comparisons can be made with Scandal Beck and River Lowther.
- **Geographic distribution of crayfish within the monitoring unit.** Show sites and abundance on a scale of distance upstream.
- **Size distribution of population.** Expect similar distributions to those seen in River Lowther and Scandal Beck, as these reflect the results of using the survey method in healthy populations.
- **Percentage population of juveniles less than 25mm CL**. If less than 25% during summer this may indicate either poor recruitment, or lower efficiency of sampling.
- **Health of population, percentage population with porcelain disease**. In northern rivers expect 3% or less. Incidence of 10% or more may indicate unfavourable condition – but note this may occur naturally if a population is present in sub-optimal habitat conditions, e.g. at the upstream end of upland catchments.
- **Percentage of adult females breeding**. This is only an indication of population health; no targets can be set because the evidence of breeding varies during the summer season.

- **Report on presence of adverse factors in monitoring unit**. See monitoring protocol, but essentially these are alien crayfish, crayfish plague, water pollution, and excessive erosion or siltation.

English Nature and Environment Agency in Cumbria share survey results. Results should also be copied to the national database, currently to the Biological Records Centre.

All crayfish surveys should be recorded using the standard survey record sheets, even if other survey methods are used. The forms can accommodate the use of other methods. They encourage greater consideration of conditions at the time of survey and local habitat characteristics relevant to crayfish, which may improve the performance of other methods. An extra column will be required in the margin of the crayfish record if a mark-release-recapture study is undertaken.

Health and safety are always important considerations in any field survey. Surveyors should make notes on access and potential hazards at sites as a guide for future surveys, although conditions may change over time. Safety needs to be assessed on arrival at any site to be surveyed. Selected notes on parking, access to the sites and conditions in the channel are recorded in Appendix Table 1. General health and safety recommendations are given in the monitoring protocol for crayfish.

In addition to the analysis and reporting listed above, the occurrence of any pollution incidents in any monitoring unit should be recorded. The Environment Agency already keeps English Nature informed of any incidents in the catchment. This should include possible problems identified during biological water quality as well as observed pollution incidents. This information and any locations with a high risk of pollution need to be cross-referenced to the crayfish database.

Any reports of possible occurrence of crayfish plague or alien crayfish anywhere in the catchment must be investigated immediately, whether or not they occur within the lengths designated as SSSI or in enclosed waterbodies in the catchment.

6. REFERENCES

Environment Agency, (1997); River Habitat Survey 1997 Field Survey Guidance Manual. Environment Agency.

Naura, M. & Robinson, M., (1998); Principles of using River Habitat Survey to predict aquatic species: an example applied to the native white-clawed crayfish *Austropotamobius pallipes*. Aquatic Conservation 8, 515-527.

Parsons, H., Walker, J., Scarlet, P. & Hornby, D., (2001); River Eden RHS and Geomorphology Evaluation. Report to Environment Agency, English Nature and Eden Rivers Trust.