Life in UK Rivers

A LIFE Nature Project

Reintroducing the White-clawed Crayfish to the River Lathkill
July 2000 – March 2002

Conserving Natura 2000 Rivers

Reintroducing the White-clawed Crayfish to the River Lathkill

Conserving Natura 2000 Rivers Conservation Techniques Series No. 8

David Rogers Associates
Aquatic Biological Consultants

For more information contact:
The Enquiry Service
English Nature
Northminster House
Peterborough
PE1 1UA
Email: enquiries@english-nature.org.uk
Tel: +44 (0) 1733 455100
Fax: +44 (0) 1733 455103

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The Enquiry Service
English Nature
Northminster House
Peterborough
PE1 1UA
Email: enquiries@english-nature.org.uk
Tel: +44 (0) 1733 455100
Fax: +44 (0) 1733 455103

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Conserving Natura 2000 Rivers

This report on a project to reintroduce the white-clawed crayfish to the River Lathkill has been produced as part of **Life in UK Rivers** – a project to develop methods for conserving the wildlife and habitats of rivers within the Natura 2000 network of protected European sites. The project's focus has been the conservation of rivers identified as Special Areas of Conservation (SACs) and of relevant habitats and species listed in annexes I and II of the European Union Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC) (the Habitats Directive).

One of the main products is a set of reports collating the best available information on the ecological requirements of each species and habitat, while a complementary series contains advice on and assessment techniques. Each report has been compiled by ecologists who are studying these species and habitats in the UK, and has been subject to peer review, including scrutiny by a Technical Advisory Group established by the project partners. In the case of the monitoring techniques, further refinement has been accomplished by field-testing and by workshops involving experts and conservation practitioners.

Life in UK Rivers is very much a demonstration project and, although the reports have no official status in the implementation of the directive, they are intended as a helpful source of information for organisations trying to set conservation objectives and to monitor for 'favourable conservation status' for these habitats and species. They can also be used to help assess plans and projects affecting Natura 2000 sites, as required by Article 6.3 of the directive.

As part of the project, conservation strategies have also been produced for seven different SAC rivers in the UK. In these, you can see how the statutory conservation and environment agencies have developed objectives for the conservation of the habitats and species, and drawn up action plans with their local partners for achieving favourable conservation status.

For each of the 13 riverine species and for the *Ranunculus* habitat, the project has also published tables setting out what can be considered as 'favourable condition' for attributes such as water quality and nutrient levels, flow conditions, river channel and riparian habitat, substrate, access for migratory fish, and level of disturbance. 'Favourable condition' is taken to be the status of Annex I habitats and Annex II species on each Natura 2000 site to contribute adequately to 'favourable conservation status' across their range.

Titles in the Conserving Natura 2000 Rivers ecology, monitoring and techniques series are listed inside the back cover of this report, and copies of these, together with other project publications, are available on the project website: www.riverlife.org.uk.

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Executive summary

To undertake the present project, 210 white-clawed crayfish (*Austropotamobius pallipes*) were taken from a large population in Bestwood Ponds in July 2000 to quarantine facilities at David Rogers Associates (Castle Donington). Of them, 162 crayfish were then transferred to holding tanks adjacent to River Lathkill to provide stock to experimentally rear juveniles in 2001 and monitor growth and mortality. The remaining 79 were introduced to a selected site in the River Lathkill in September 2000.

All the crayfish were individually marked using pleural and uropodal clipping to enable identification of individuals for monitoring purposes throughout this project.

It was found the stock comprised a large ratio of males/females (75:25). They were separated into three tanks only one of which contained a breeding population – 50:50 males/females. Mortality, growth and behaviour of all crayfish were monitored.

In 2000, only limited success of rearing juveniles in captivity was achieved. Therefore in 2001, six ovigerous females were removed to aquaria for closer observation and the remainder were placed in improved conditions by the use of larger individual cages inside a small mesh cage to act as a Control.

During the project ovigerous females held in captivity produced similar numbers of eggs but fewer juveniles to those found in the wild. Close observation of the females revealed that many eggs were dislodged by the behaviour of the adult and some juveniles are certainly eaten by adults, but the fate of the majority of the juveniles has not been fully discovered by the present study.

By June 2001 all the juveniles in aquaria were independent of the females and transferred to a variety of experimental locations to monitor survival and growth.

Most juveniles survived approximately four weeks after being transferred but died before or during the first free living moult (Stage 3). The exceptions were the juveniles held in a folded flexible net in a large tank; of these 17 Stage 3 juveniles in June 2001, 11 survived until November 2001 undergoing several moults and reaching an average carapace length of 10 mm. It was thought that the extra cover provided by the folds of the net contributed to good survival.

No surviving juveniles were found in the control location despite the use of larger individual cages.

The adult crayfish survival rate was significantly lower in tanks containing only males (35% in male only tanks and 48% in mixed sex tanks). This may be due to increased aggression in populations with a large proportion of males. During the study period carapace length increased in all the surviving crayfish, the greatest in male only tanks.

Since the introduction of 79 crayfish directly to the River Lathkill in September 2000, despite severe drought and drying up of the river further downstream, there have been sightings of crayfish around the release site. This indicates the re-introduction has been successful to date although to ensure a long-term viable population further additions of crayfish stock may be required.

The project has the potential to continue under the stewardship of the Haddon Estate and there are opportunities for trials of improved methods of rearing juveniles.

1 Background

This project is part of the **Life in UK Rivers** project for conserving Natura 2000 rivers. One of the aims of this project is to develop practical techniques to expand the range or increase populations of white-clawed crayfish where a suitable habitat is available but not utilised due to historical impacts.

To quote the LIFE Framework Document: "There are strong arguments for reintroducing crayfish to suitable sites where they have been lost, particularly when non-native species are not established and factors such as obstructions make a natural re-colonisation unlikely…."

The River Lathkill lost the entire population of white-clawed crayfish in a mass mortality in 1993. This may have been caused by crayfish plague spores imported on trout but it should be noted that there is no evidence of the spores being imported on trout and no confirmation of plague being the cause of mortality in this case. Nevertheless, the white-clawed crayfish population was reputedly a strong one until 1993 when a mass mortality occurred bearing all the hallmarks of a crayfish plague outbreak, and no crayfish were found in the Lathkill between 1993 and 1998 (Rogers 1998).

The project comprises an experimental reintroduction looking at methods of rearing suitably large numbers of white-clawed crayfish from relatively small numbers of imported stock. If achieved this will increase the potential for success of the reintroduction in the face of predation while limiting impacts on donor populations, therefore ensuring that introduced stock can be from as local a provenance as possible, even if these populations are relatively small, given that genetic dissimilarity is perceived as a possible problem in such re-introductions. As the project had a limited timetable the reintroduction was primed by introduction of numbers of older stock but it would be recommended that only stock reared in captivity be introduced if this project proves successful.

The present project follows a pilot reintroduction project, which demonstrated that the River Lathkill could support white-clawed crayfish in 1999/2000, despite them all being killed in 1993.

The Haddon Estate was a proponent of this project. Permanent staff, the river keeper and his assistant, were to be involved and existing facilities adjacent to River Lathkill were to be utilised as much as possible such that when the UK LIFE element of the project ended in 2002, the estate might be able to continue breeding and reintroducing crayfish.

2 Aims and objectives

The overall aims of the project are to:

- Research a method of reintroduction that utilises relatively small numbers of individuals from donor populations.
- Research methods of rearing white-clawed crayfish from stock.
- Provide information on growth rates, mortality, sex ratios, age/size class recruitment and population growth.
- Initiate the reintroduction of white-clawed crayfish into the River Lathkill.
- Demonstrate a reintroduction process to other land managers appropriate for sites with similar circumstances.

In order to achieve these aims the project had the following objectives, which were undertaken over two years:

- Transfer crayfish to holding facilities adjacent to River Lathkill so that their growth and survival could be monitored.
- Monitor the progress of juvenile crayfish held in captivity.

- Devise a rearing method for juveniles.
- Devise or select a suitably robust method of marking crayfish for monitoring following release to the wild
- Select an appropriate site on the River Lathkill for reintroduction.

3. Transfer of crayfish to holding facilities adjacent to River Lathkill

The donor population was a large population of white-clawed crayfish located in Bestwood Ponds (SK 495 555), which, according to anglers, would not be affected by the removal of hundreds or thousands of individuals. English Nature and the Environment Agency also approved of crayfish being taken from this site for research during the present project and an appropriate licence to take crayfish was issued under the Wildlife and Countryside Act 1980.

Between July and September 2000, over 200 crayfish traps were laid at Bestwood Ponds. The crayfish caught were transported to a holding site at David Rogers Associates (Castle Donington) and kept in a quarantine holding tank, in tap water (chlorinated) for at least 7 days. The purpose of the quarantine facility was to reduce the chance of fish disease transfer during the crayfish transfer. A total of 162 crayfish were transferred to concrete tanks adjacent to River Lathkill on the River Lathkill (SK 214 652).

A food source of fresh weed with its compliment of associated invertebrate fauna from the river was provided for crayfish in captivity as required.

These crayfish provided a stock whose mortality and growth could be monitored and which could provide juveniles in captivity for the project in 2001.

It was found that there were a disproportionate number of males (approximately 75%) and no small crayfish had been trapped (< 26 mm carapace length). This concurs with recent studies; Smith & Wright (2000) who demonstrated that crayfish traps were size-selective and Wright & Williams (2000) who suggested that males are more likely to be caught in the warmer months. A 50:50 proportion of males:females would have provided a more suitable population for the present project, but we worked with the animals caught.

4. Marking crayfish for monitoring

The following points were important in the present study:

- The marks made by the method chosen, pleural and uropodal clipping were known from previous experience to last for at least two moults.
- A requirement was that the marking system was effective for a complete year.
- The crayfish studied might be expected to moult once or at a maximum twice annually.
- As the crayfish were marked in September 2000, it was anticipated that this would allow the opportunity of monitoring crayfish progress over the duration of the field studies in present project.

The system adopted for marking crayfish was pleural and uropodal clipping, as this fulfils the following requirements for recapture studies (Chien & Avault 1979):

- Marks must not be lost post-moult.
- Marks must not affect survival, including susceptibility to predation.

- Marks must be distinguishable from other abnormalities.
- The method must be applicable to all stages of the moult cycle.
- Marks must not affect moulting, growth or behaviour patterns.
- The method must be quick and effective in field conditions.
- The marking system must be able to cope with large numbers.

5. Monitoring mortality and growth

Mortality and growth of crayfish held adjacent to River Lathkill were monitored over the year October 2000 – October 2001.

5.1 Adult crayfish

On 25/10/00 each crayfish being held adjacent to River Lathkill was individually marked and sex, carapace length, weight and any other comments recorded.

In order to research growth and mortality and provide a breeding population the crayfish were separated into the three available tanks (Appendix 1).

On 15/05/01 and 17/10/01 these crayfish were recaptured and details recorded again (Appendix 1

5.1.1 Adult survival

During the first stage of the experimental period (25/10/00 – 15/05/01) the majority of mortalities occurred in the largest crayfish (carapace length >47 mm).

The survival rates of adult crayfish in Tanks 1 and 2 are summarised in Table 1.

Table 1: Survival rates of crayfish held in Tanks 1 & 2 adjacent to River Lathkill.

Location	**No. of crayfish found on**			
	25/10/00	15/05/01	17/10/01	Survival rates
Tank 1				
Males	30	21	15	50%
Females	32	24	15	47%
Males & females	62	45	30	48%
Tank 2				
Males only	23	13	8	35%
Overall survival rate				45%

There was a significantly higher mortality in the tank that contained males only. This may be because populations with large numbers of males are more prone to cannibalism and behave in a more aggressive manner leading to fighting and death.

The visit on 17/10/01 revealed a hole in the Tank 3, enabling a large proportion of crayfish to escape - Figure 1. Only three crayfish were found out of 45 introduced and therefore Tank 3 was excluded from all results.

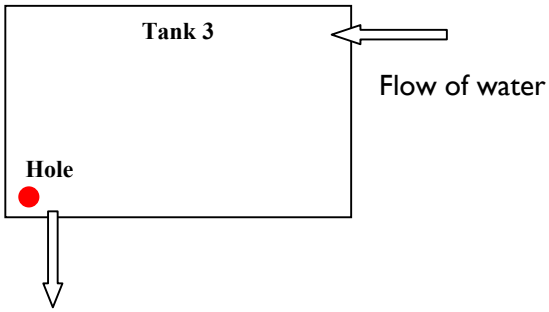

Figure 1: Diagram illustrating hole in Tank 3, 17/10/01.

5.1.2 Adult growth rates

The carapace lengths of the crayfish held adjacent to River Lathkill were measured on 25/10/00, 15/05/01 and 17/10/01 to assess growth (Appendix 1).

The results are summarised in Figure 2, which illustrates the carapace length frequency of all surviving crayfish (those crayfish that died during the experimental period have been removed from the dataset).

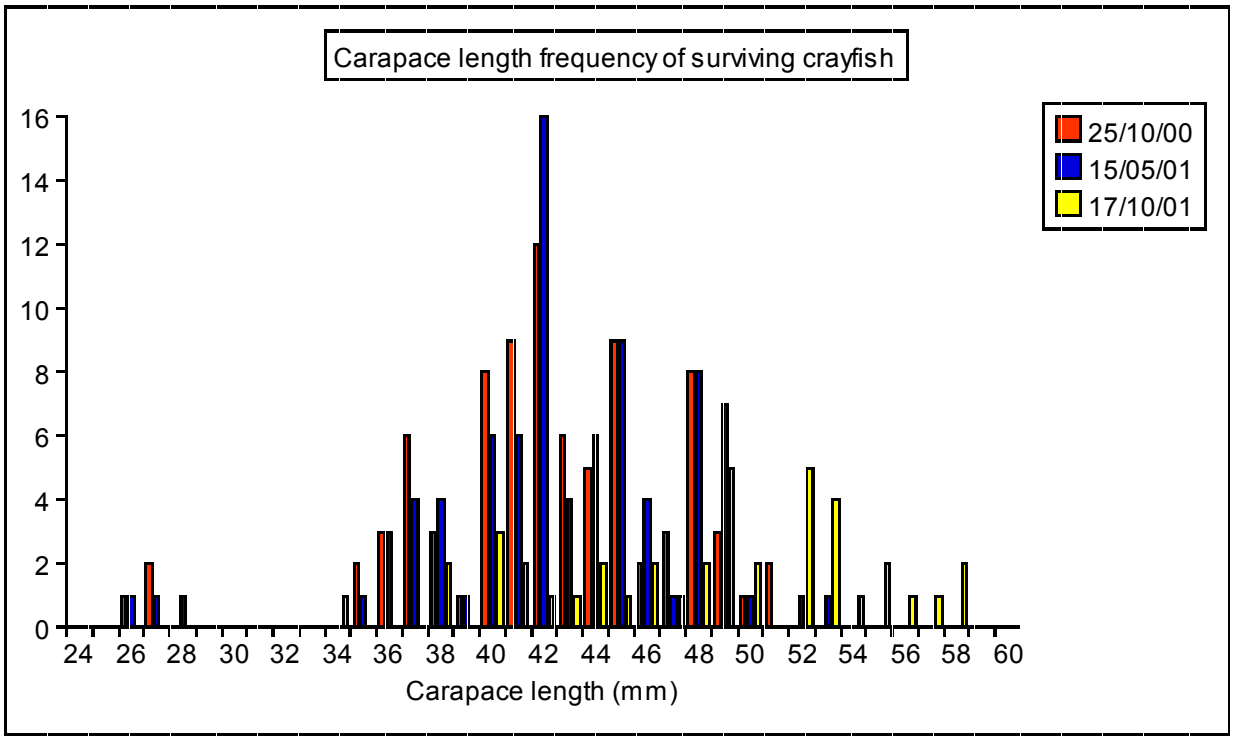

Figure 2. Carapace length frequency histogram of crayfish on 25/10/00, 15/05/01 and 17/10/01.

From these data the growth of crayfish during winter and summer has been calculated and is illustrated in Figure 3.

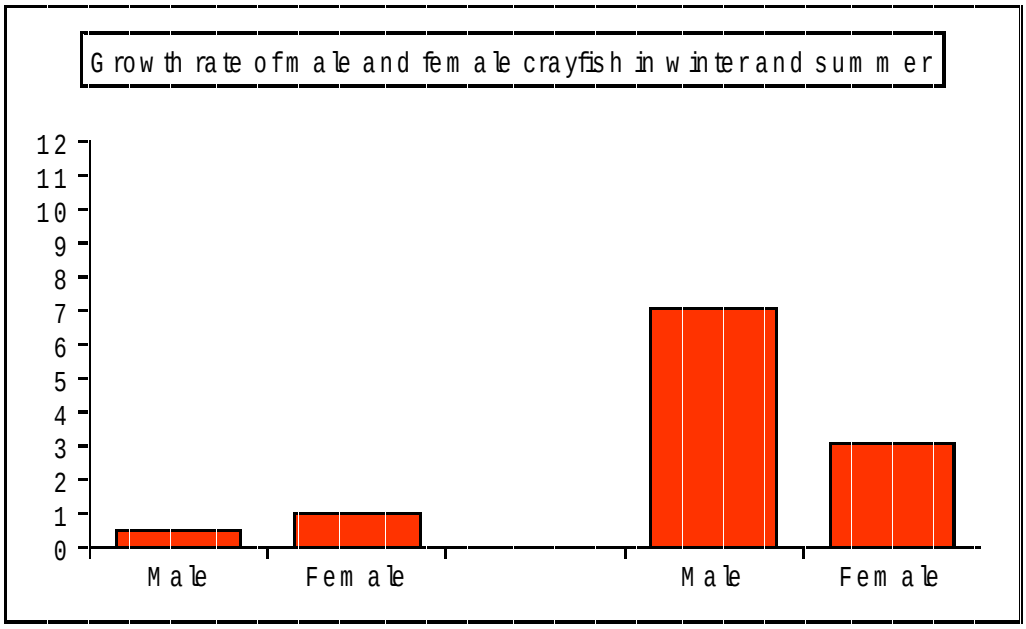

Figure 3: Range and average growth of male and female crayfish in winter and summer. The average growth in winter (25/10/00 – 15/05/01) was 0.5 mm for adult males and 1 mm for adult females. In summer (15/05/01 – 17/10/01) the average growth for males was 7.1 mm and 3.1 mm for females.

Moulted exoskeletons were found in all tanks throughout the year, demonstrating ecdysis and strongly suggesting that growth was occurring.

Between 25/10/00 and 15/05/01 (winter period) there was a small increase in carapace length, approximately 1 mm in half of the crayfish. Over the summer period of the experimental period, i.e. 15/05/01 – 17/10/01, there was an increase in carapace length in all crayfish. The growth rates are summarised in Table 2 as a percentage increase in carapace length for adult crayfish using the equations:

Where
N = Number of crayfish in sample
L_1 = Original length of carapace (25/10/00)
L_2 = Length of carapace (15/05/01)
L_3 = Length of carapace (17/10/01)

$$\% \text{ growth in winter (25/10/00 – 15/05/01)} = \left[\frac{\sum L_2 - L_1}{N} \right] 100$$

$$\% \text{ growth in summer (15/05/01 – (17/10/01)} = \left[\frac{\sum L_3 - L_2}{N} \right] 100$$

$$\% \text{ overall growth (25/10/00 – 17/10/01)} = \left[\frac{\sum L_3 - L_1}{N} \right] 100$$

Thus:

$$\% \text{ increase in length} = \frac{\text{Average growth of surviving crayfish}}{\text{Average of original length of crayfish}} \times 100$$

Table 2: Growth of adult crayfish

Location of crayfish	Growth over winter period 25/10/00 – 15/05/01	Growth over summer period 15/05/01 – 17/10/01	Annual growth of surviving crayfish 25/10/00 – 17/10/01
Tank 1			
Males	1.1%	15.1%	16.7%
Females	2.0%	7.1%	9.1%
Males and females	1.6%	11.1%	12.9%
Tank 2			
Males only	1.1%	20.4%	21.5%

It should be noted that males appeared to survive better in the presence of females (Table 1) but growth was greater in male only tanks (Table 2). Female growth was found to be considerably less than male growth (Figure 4).

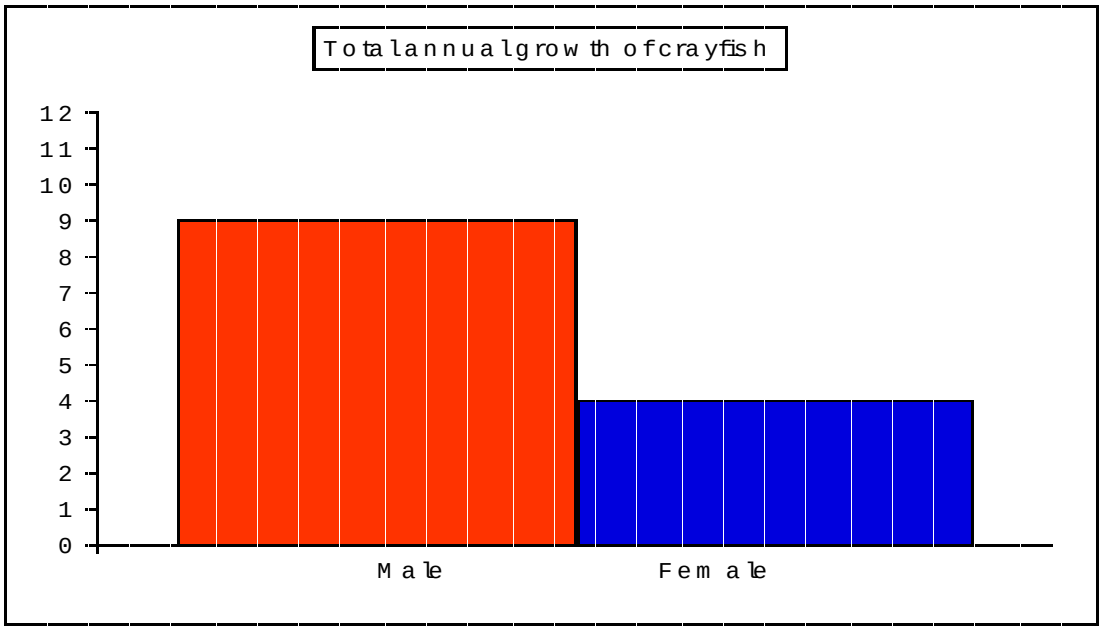

Figure 4: Comparison of annual average growth and range in male and female crayfish.

5.1.3 Moderating Factors

Our sample, consisting of all those crayfish captured from Bestwood Ponds surviving adjacent to River Lathkill on 25/10/00, was dominated by large males (75:25) the remainder being large females. This is thought to be unrepresentative of wild populations, which have approximately a 50:50 male/female sex ratio and contain a large percentage of young crayfish, which escaped trapping.

The pleural and uropodal marks made on the crayfish in October 2000 were becoming difficult to distinguish by October 2001. It would appear from the growth increases that most crayfish had moulted over the year and some crayfish showed signs of problems where the uropod had been cut. Where markings were impossible to distinguish (in two crayfish) their growth rates have been omitted from the results.

Monitoring growth patterns involved hand measuring from the tip of rostrum to the base of abdomen. These measurements are subject to some slight error and inaccuracy.

5.2 Juveniles reared in captivity

The aim of rearing juveniles in captivity was to try to enhance the survival of juvenile crayfish.

5.2.1 Rearing juveniles in 2000

During the pilot study (1999 – 2000) individual cages (15 cm x 10 cm x 10 cm with mesh dimensions: rigid 8 mm knot-to-knot square mesh) had been used to try to prevent the females from predating on the juveniles which were small enough to escape from the individual adult crayfish cages. A one cubic metre ($1m^3$) fine meshed cage retained the juveniles (mesh dimensions: 2 mm-diameter circular). The individual cages had also been supported away from the bottom of the tank that they were held in to avoid bacteria and fungi.

This situation was taken over by the present project in April 2000, 10 ovigerous females (introduced during the pilot project) were held in captivity in individual cages adjacent to River Lathkill (Photo 1, Appendix 2).

On 01/04/01, the average number of eggs held by each female was estimated at 40.

On 20/06/00, the eggs were observed hatching and there did not appear to be any losses.

On 10/07/00, the number of Stage 2/3 juveniles was estimated at 40 per adult.

On 31/07/00, it was observed that the juveniles had left the adults. The adults in their individual cages were removed, leaving the juveniles in the fine mesh cage. Only 13 juvenile crayfish could be found.

The fate of the majority of potentially free-living juvenile crayfish (400) was not known. Possibilities included:

- Heavy predation by the adult females as the juveniles left the adult while they were in the individual female crayfish cages.

- Escape of juveniles through the 2 mm mesh of the of the $1m^3$ fine mesh cage.

The juvenile crayfish were monitored on two further occasions. Details are shown in Table 4.

Table 4. Details of juveniles held in fine mesh cage adjacent to River Lathkill.

Date	Number of eggs/ juveniles	Juvenile stage	Average total length (mm)	Comments
01/04/00	40x10 = 400 eggs (estimate)	Eggs		
20/06/00	40x10 = 400 eggs hatching (estimate)	Eggs hatching		
10/07/00	40x10 = 400 juveniles (estimate)	Stage 2		
31/07/00	13	Stage 3	10	2 with 1 claw (Photo 2, Appendix 2)
30/08/00	11	Stage 3	12	1 with 1 claw
26/09/00	5	Stage 3	12	2 with 1 claw
15/05/01	1	Stage 3	14	Transferred to individual cage
20/05/01	0			All juveniles found dead

The rearing of juveniles hatched in 2000 in the facilities available (Photo 1, Appendix 2) was not successful so those hatched in 2001 were observed more closely (see Section 6.2.2).

5.2.2 Rearing juveniles in 2001

The female crayfish held in Tank 1 provided juveniles for 2001. However, when these were examined on 15/05/01 the number of surviving females with eggs was disappointing – only 24 (75%) females had survived and of these only 13 (41%) had four or more eggs (Table 5). They were assigned to holding facilities as shown in Table 5.

Table 5. Details of surviving females 15/05/01

Crayfish marked as number	Carapace length (mm) 15/05/01	Weight (g) 15/05/01	Comments	Holding facility
91	48	28	1 claw, no eggs	Tank 1
122	43	23	9 eggs	Individual mesh cage in Tank 1
130	42	19	1 claw, no eggs	Tank 1
131	40	20	52 eggs	Aquarium
141	44	26	32 eggs	Individual mesh cage in Tank 1
144	40e	24	73 eggs	Aquarium
149	42	21	9 eggs, 1 orange	Individual mesh cage in Tank 1
151	42	21	No eggs	Tank 1
153	38	16	No eggs	Tank 1
155	38	17	25 eggs	Individual mesh cage in Tank 1
156	36	12	1 claw, no eggs	Tank 1
158	38	13	12 orange eggs	Individual mesh cage in Tank 1
161	37	14	47 eggs	Aquarium
184	39	18	19 eggs	Individual mesh cage in Tank 1
185	41	23	No eggs	Tank 1
186	41	26	46 eggs	Aquarium
187	37	16	38 eggs	Aquarium
188	43	23	No eggs	Tank 1
190	37	18	No eggs	Tank 1
191	35	15	24 eggs	Individual mesh cage in Tank 1
192	36	14	4 eggs	Tank 1
206	42	21	4 eggs	Tank 1
207	40	22	87 eggs	Aquarium
210	41	20	4 eggs	Tank 1

In order to research the behaviour of the females and the fate of the juveniles, six ovigerous females were transferred to aquaria for daily observation.

Seven females with between four and 35 eggs were placed in individual cages in Tank 1 (the method used in the Pilot Project).

The remaining 11 females (those with less than four eggs) were replaced in Tank 1.

As the method of rearing juveniles during the Pilot Project in a $1m^3$ mesh cage resulted in only one live crayfish (after 10 months of independence this crayfish subsequently died) four new methods were devised.

Remove juveniles as they leave the female and hold in a separate aquarium (Photo 3, Appendix 2)

Remove juveniles as they leave the female and hold in a separate aquarium for four weeks then transfer them to the fine mesh cage in Tank 1.
Remove juveniles as they leave the female and hold in a titanium mesh tank selected due to inert properties of titanium (Photo 4, Appendix 2).

Remove juveniles as they leave the female and hold in a small, partially covered fine mesh flexible net (approximately 25 cm^2) hanging in a large tank (Photo 5, Appendix 2).

The seven females held in individual cages in Tank 1, (as in the Pilot Project) acted as a control. Table 6 summarises the results.

Table 6. Progress of juveniles in 2001

Crayfish marked as number	Number of eggs	Date eggs hatched	Date juveniles left female & number of juveniles	Location of juveniles	Comments and progress
131	52	24/05/01	26/05/01 13juveniles	Separate aquarium	Moved to cage in Tank 1 on 25/06/01 11juveniles. Could not be found thereafter
144	73	–	–	–	In aquarium with No. 187, lost all eggs fighting and scratching with back legs
161	47	16/06/01	21/06/01 17 juveniles	Flexible net in large tank	All 17 moulted and survived to stage 3, 11 still alive – 15/10/01
186	46	08/06/01	18/06/01 25 juveniles	Titanium tank	All juveniles dead – 20/07/01
187	38	1/06/01	05/06/01 18 juveniles	Separate aquarium	All juveniles dead – 25/07/01
207	87	27/05/01	31/05/01 14 juveniles	Separate aquarium	Moved to cage in Tank 1 on 25/06/01 7 juveniles. Could not be found thereafter
Females in individual cages in Tank 1 on 15/05/01					
122	9	7 eggs not hatched			
141	32	22 eggs not hatched			
149	9	2 eggs not hatched			No surviving juveniles were found in the 1m³ mesh cage on 25/08/01
155	25	17 eggs not hatched			
158	12	8 bright orange eggs (orange indicates eggs are dead)			
184	19	12 eggs not hatched			
191	24	17 eggs not hatched			

Most juveniles died within one month of leaving the adult. Only those juveniles held in flexible netting (net curtain material) survived until the end of the first summer.

5.2.3 Observations of aquarium crayfish

Pairs of berried females kept in a single aquarium spent a considerable amount of time fighting despite the aquarium containing several suitable hides. This behaviour resulted in the loss of most eggs
Several females displayed unusual behaviour, for example, scratching with back legs and exposing their eggs directly to a strong airflow from an aeration store. Both these behaviours resulted in the loss of eggs
One female was observed eating her Stage 2 young during their efforts to leave the adult
The juveniles appeared to take several days to become completely independent and fully leave the adult.

6 Discussion of rearing juveniles in captivity

It was not thought that juveniles escaped from any of the facilities used. The success of the facilities is summarised below:

Table 7: Success of facilities for juvenile rearing

Rearing facility	Juvenile survival
1m³ mesh cage	Not successful beyond second moult
Titanium mesh cage	Not successful beyond second moult
Folded net curtain cage	Most successful 65% survival over 6 months
Aquaria	Not successful beyond first moult

Most facilities constructed for holding juvenile crayfish were unsuccessful with juveniles only surviving approximately four weeks after being transferred and dying before or during the first free living moult (Stage 3). The exceptions were the juveniles held in a folded flexible net in a large tank where the extra cover provided by the folds of the net is believed to have contributed to good survival. Of 17 Stage 3 juveniles in June 2001, 11 survived until November 2001 undergoing several moults and reaching an average carapace length of 10 mm.

Despite the use of larger individual cages no surviving juveniles were found in the control location.

The use of aquaria did yield valuable observations of both adult and juvenile behaviour – for example, adult eating Stage 2 juveniles. More juveniles survived initially if they were manually removed from the adult a few days after the eggs had hatched but before they left naturally because this reduced the opportunity of female predation.

The opportunity for continued improvement of juvenile rearing facilities could be explored in future years under the stewardship of the Haddon Estate.

7 Crayfish introduced to River Lathkill release site

In September 2000, 79 crayfish surplus to needs had been trapped from Bestwood Ponds and quarantined at David Rogers Associates (Castle Donington). The tanks adjacent to River Lathkill held sufficient crayfish for supply of broodstock the following year. Addition of further crayfish to these tanks would be likely to increase cannibalism. Therefore on 26/09/00 these 79 crayfish were introduced directly from the quarantine facility to the River Lathkill.

The release site was selected based on the habitat requirements of the white-clawed crayfish (Holdich & Rogers 2000) but also taking into consideration that a site with reasonable access for monitoring and not interfered with by the general public was needed.

The site selected (SK 184 658) is downstream of a small waterfall with moderately fast flowing water and with a bed of stones and boulders to provide hides. It is within the Derbyshire Dales National Nature Reserve, a Site of Special Scientific Interest and a Special Area of Conservation under the European Habitats Directive.

In order to monitor the movement and population of crayfish introduced into the River Lathkill, each crayfish was marked individually using pleural and uropodal clipping.

Details of the crayfish released and a carapace length frequency histogram can be found in Appendix 3.

Following release, monitoring was undertaken as follows:

- In May 2001 English Nature staff searched the vicinity of the crayfish introduction site for crayfish. No crayfish were found.
- On 04/07/01 English Nature staff again searched the area and found one crayfish 200 m downstream of the introduction site.
- On 25/08/01 David Rogers Associates searched a 300 m stretch of the River Lathkill downstream of the introduction site. No crayfish were found.
- In October 2001 English Nature staff observed crayfish while undertaking remedial works 300 m downstream of the introduction site.

Sighting of crayfish in the vicinity of the release site indicate that some of the introduced crayfish did survive at least one year and it is possible that breeding may have occurred although we have no evidence. It is well known that the detection of low-density crayfish populations is difficult. As the habitat that the crayfish were introduced to consists of very large numbers of rocks and stones, even extended periods of searching may not expose areas which could be occupied by the introduced crayfish. Therefore it may be worthwhile to attempt trapping for monitoring purposes in the future.

8 Conclusion

White-clawed crayfish have been re-introduced to the River Lathkill and reared and bred in river water adjacent to the Lathkill during this project. Adult crayfish grew well in captivity and breeding was successful but rearing the juveniles after they left the adults proved difficult with the experimental facilities available. Almost all juvenile crayfish were lost in their early moults of independent existence. This is thought to be due to their requirement for cover which was not satisfied in all but one of the experimental facilities.

Juvenile crayfish are very vulnerable to predation (from each other and the adults as well as other predators) when they first become independent especially during moulting which is a regular ordeal during the first summer of their life; moulting occurs up to seven times during the first summer. Thus it can be surmised that their requirement for each individual to find a secluded and secure habitat regularly is of paramount importance for survival. During the present project the best material found to provide this cover was loosely hung net curtain; surprisingly this material produced better survival than natural weed from the river.

Removal of juveniles from the adult crayfish soon after hatching gave a higher proportion of immediate survival than leaving them on the female even if the female was individually caged. The aquaria results appeared to show that the juveniles did not get out of range of the mother quickly enough. There was no

evidence of any chemical (pheromone) encouraging mothers not to eat the young as had been suspected in scientific literature.

A full year's data was recorded for mortality and growth of adult crayfish and two years data was collected for juvenile crayfish. This was considered reasonably successful given the limited time-scale and the fact that there was not a true cross section of a population (all the crayfish stock were large adults and mostly male).

Survival is difficult to estimate when the possibility of escape exists (as it does in almost any wild environment) but in the present project 45% survival over one year was recorded. Thus it can be concluded that survival is 45% or greater per annum under these conditions.

Average adult growth of 5 mm (9.1%) in females and 7 mm (21.9%) in males was recorded over the same year. Although no further statistics have been applied the authors are confident of these results because they are based on records of 53 male and 32 female individually marked crayfish (rather than batches).

Although care was taken not to overstock the holding facilities, the environment did not emulate that of a wild habitat. Crayfish movement was extremely limited; the escape of most of the males in the Tank 3 suggests wild populations cover a more expansive range or were seeking a more suitable environment. The availability of natural hides was limited (provision of pipes replaced natural good crayfish habitat, which might include soft bank areas and a range of cobbles and boulders). These factors may have increased competition and aggressiveness thereby decreasing survival especially in competitive males.

Incremental growth was larger in males than females and greatest in male only populations, which is consistent with males growing larger in the wild.

9. Prospects for further work

At the completion of this project a sufficient quantity of crayfish were left in tanks 1 & 2 at Adjacent to River Lathkill to undertake further experimentation with breeding.

It is recommended that before the juveniles leave the mother they are picked off and housed in an environment where they can find secure places to hide during moulting – for example, a secure small mesh cage with sufficient bunched net curtain material included.

Further attempts to improve juvenile survival rates could be made by removing them at different stages (at egg stage before hatching to when they leave the adult naturally).

The use of crayfish traps to verify presence of crayfish in the vicinity of the reintroduction site should be considered.

It is not known how many crayfish are needed for the population in the Lathkill to be genetically viable but it is possible that further crayfish will need to be imported for this purpose.

Acknowledgements

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Appendix 1: Growth, mortality and location of crayfish

Crayfish marked As number	Sex	Carapace length (mm) 25/10/00	Weight (g) 25/10/00	Comments 25/10/00	Tank Location 25/10/00	Carapace length (mm) 15/05/01	Weight (g) 15/05/01	Comments 15/05/01	Carapace length (mm) 17/10/01	Weight (g) 17/10/01	Comments 17/10/01
80	M	50	40		2	50	41		58	64	
81	M	45	27	1 claw	3	*	*		*	*	
82	M	52	51		2	*	*		*	*	
83	M	47	42		3	49	41		*	*	
84	M	47	40		1	*	*		*	*	
85	M	45	28		2	45	30		52	47	
86	M	56	56		2	*	*		*	*	
87	M	48	38		3	48	39		*	*	
88	M	55	54	Abdomen damaged, 1 claw regenerated	1	*	*		*	*	
89	M	46	34		3	*	*		*	*	
90	M	47	42		3	48	41		*	*	
91	F	48	32		1	48	28	1 claw	49	33	1 claw
92	M	48	36		1	48	36		49	48	
93	M	47	35		3	*	*		*	*	
94	M	47	32		2	*	*		*	*	
95	M	45	29	1 claw	3	46	29	1 claw	*	*	
96	M	48	42		1	*	*		*	*	
97	M	45	30		3	*	*		*	*	
98	M	51	47		1	52	47		*	*	
99	M	50	45	Nearly dead	3	*	*		*	*	
100	M	46	34		1	48	33		55	60	
101	M	50	46		3	*	*		*	*	
102	M	48	40		2	49	41		57	71	
103	M	46	34		3	*	*		*	*	

104	M	48	42		2	49	42		*	*	
105	M	45	34		3	47	34		*	*	
106	M	44	30		3	*	*		*	*	
107	M	45	33		3	45	33		*	*	
108	F	45	28	Nearly dead, mated	1	*	*		*	*	
109	M	43	25	Abdomen damaged, 1 claw	3	*	*		*	*	
110	M	45	27		1	45	27		56	57	
111	M	41	26		3	43	25		52	52	
112	M	43	28		2	45	28		*	*	
113	M	43	22	Almost dead, 1 claw	3	*	*		*	*	
114	M	42	24		1	42	25		50	40	1 claw
115	M	41	25		3	41	25	1 claw regenerating, missing uropod	*	*	
116	M	42	27		1	42	28		42	22	
117	M	42	28		3	42	28		*	*	
118	M	42	28		1	42	26		48	39	
119	M	44	31		3	*	*		*	*	
120	M	45	30		2	45	30		*	*	
121	F	43	29	Mated and with eggs	1	*	*		*	*	
122	F	43	23	Mated and with eggs	1	43	23	9 eggs	*	*	
123	M	42	22		3	42	23		53	48	
124	M	50	34		2	*	*		*	*	
125	M	41	28		3	42	26		*	*	
126	M	44	28		2	44	28		55	53	
127	M	41	26		3	*	*		*	*	

128	M	41	25		1	42	25		52	48	
129	F	41	26	Mated and with eggs	1	*	*		*	*	
130	F	42	21	Glair, no eggs	1	42	19	1 claw, no eggs	43	20	1 claw
131	F	38	19	Mated and with eggs	1	40	20	52 eggs	45	28	
132	M	43	27	1 claw regenerating	1	45	25	1 claw regenerating	52	39	
133	F	42	26	Mated and with eggs	1	*	*		49	36	
134	M	41	25		1	*	*		*	*	
135	M	40	25		1	40	28		*	*	
136	M	41	23		2	42	23		*	*	
137	M	44	27		3	45	29		*	*	
138	M	48	33		1	48	33		*	*	
139	M	44	28	Abdomen damaged	3	44	28		*	*	
140	M	42	22	1 claw	2	44	22	1 claw	53	43	1 claw
141	F	43	26	Mated, glair, no eggs	1	44	26	32 eggs	*	*	
142	M	41	22		2	*	*		*	*	
143	M	40	21		3	40	21		*	*	
144	F	40e	22	Mated, no eggs	1	40e	24	73 eggs	*	*	
145	M	41	22		3	41	22		*	*	
146	M	42	19	No claws	1	42	19	No claws	48	28	
147	M	40	22		3	41	22		*	*	
148	M	42	25		2	*	*		*	*	
149	F	42	19	No eggs, glair, not mated	1	42	21	9 eggs – 1 orange	*	*	
150	M	40	18	1 claw	2	*	*		49	32	
151	F	40	21	Mated and	1	42	21	No eggs	*	*	

				with eggs							
152	M	41	26		1	42	26		52	49	
153	F	37	16	Mated and with eggs	1	38	16	No eggs	40	17	
154	M	37	14	1 claw	1	38	15	1 claw	44	22	
155	F	38	16	Glair, not mated	1	38	17	25 eggs	41	20	
156	F	36	14	Glair, not mated, no eggs	1	36	12	1 claw, no eggs	40	21	
157	M	40	17	1 claw	3	40	18	1 claw	*	*	
158	F	33	12	Glair, no eggs	1	38	13	12 orange eggs	38	15	
159	M	39	19		2	40	20		*	*	
160	M	36	14		1	36	14		*	*	
161	F	37	14	Glair, no eggs	1	37	14	47 eggs	*	*	
162	M	37	14		2	*	*		*	*	
163	M	27	5		3	27	5		*	*	
164	M	26	5		2	26	5		34	10	
165	M	27	5		3	28	6		*	*	
166	M	34	12	Thelohania – killed		*	*		*	*	
167	M	48	47		3	49	46		*	*	
168	M	49	46		1	49	44		*	*	
169	M	50	44	Carapace damaged	3	*	*		*	*	
170	M	51	40		1	53	41		*	*	
171	M	50	37		3	*	*		*	*	
172	M	54	49		1	*	*		*	*	
173	M	48	37		3	48	36		*	*	
174	M	44	28		2	44	29		53	46	
175	M	45	34		3	46	36		*	*	
176	M	46	34		1	*	*		*	*	

177	M	48	39		3	*	*		*	*	
178	M	50	36		1	*	*		*	*	
179	F	46	30	Carapace & abdomen damaged, mated and with eggs	1	46	30	No eggs	50	34	
180	M	51	39		2	*	*		*	*	
181	M	44	32		3	46	32		*	*	
182	M	40	22		1	*	*		49	44	
183	F	40	17	Eggs	1	*	*		*	*	
184	F	38	18	Glair, not mated	1	39	18	19 eggs	41	21	
185	F	41	22	Eggs	1	41	23	No eggs	46	26	
186	F	40	26	Eggs	1	41	26	46 eggs	*	*	
187	F	37	16	Glair, no eggs, not mated	1	37	16	38 eggs	*	*	
188	F	43	23	Mated, glair, no eggs	1	43	23	No eggs	46	25	
189	F	42	24	Eggs	1	*	*		*	*	
190	F	37	16	Mated, 1 egg	1	37	18	No eggs	*	*	
191	F	35	15	Mated and with eggs	1	35	15	24 eggs	38	15	
192	F	36	14	Eggs	1	36	14	4 eggs	*	*	
193	F	45	23	Mated, no eggs	1	*	*		*	*	
194	M	40	21		2	*	*		*	*	
195	M	47	33		3	*	*		*	*	
196	M	47	33		2	48	34		58	65	
197	M	37	16		3	37	16		*	*	
198	M	49	40		1	49	40		53	51	
199	M	43	26		3	*	*		*	*	
200	M	45	33		1	45	33		*	*	

201	M	49	39		3	49	39		*	*	
202	M	45	32		1	45	32		54	52	
203	M	43	23		3	*	*		*	*	
204	M	50	39		1	*	*		*	*	
205	M	43	26		3	43	26		*	*	
206	F	42	19	Glair, no eggs, not mated	1	42	21	4 eggs	*	*	
207	F	40	21	Mated, glair, no eggs	1	40	22	87 eggs	44	27	
208	M	42	23	1 claw	1	44	23	1 claw	*	*	
209	M	44	27		3	*	*		*	*	
210	F	41	19	No eggs	1	41	20	4 eggs	*	*	

* crayfish missing presumed dead on 15/05/01.

Appendix 2: Project photographs

Photo 1: Preparing individual cages for placing in 1m³ fine mesh cage (black). Tank 2 is behind black fine mesh tank and the River Lathkill in the background.

Photo 2: Juveniles reared in captivity 30/08/00.

Photo 3: Experimental rearing facility – titanium cage to be placed in large tank.

Photo 4: Experimental rearing facility – held in separate aquarium.

Photo 5: Experimental rearing facility – partially covered with a tile, a fine mesh flexible net held in large tank, the most successful of the experimental facilities.

Appendix 3: Details of crayfish introduced to River Lathkill 26/09/00.

Crayfish marked as number	Sex	Carapace Length (mm)	Weight (g)	Notes
1	M	45	28	
2	M	46	34	
3	F	43	23	
4	M	46	33	
5	F	40	17	
6	M	49	34	1 claw
7	M	46	34	
8	M	45	32	
9	M	51	46	1 claw damaged.
10	M	45	33	
11	M	50	41	1 claw
12	M	45	26	
13	F	43	21	
14	M	46	37	
15	M	51	39	
16	M	50	36	1 claw
17	M	54	56	
18	M	47	40	
19	M	42	24	
20	F	35	13	
21	F	40	19	
22	M	45	21	No claws. Damaged uropod
23	M	47	40	
24	M	41	23	1 claw
25	M	41	21	1 claw
26	M	39	21	
27	F	45	26	
28	M	40	24	
29	F	45	26	
30	M	44	27	
31	F	41	19	
32	F	41	20	
33	F	43	23	
34	F	40	21	
35	F	37	16	
36	F	45	24	
37	M	42	23	
38	F	37	15	
39	F	45	26	
40	M	43	30	
41	M	40	19	
42	F	42	19	
43	M	45	24	No claws.
44	M	44	25	1 claw

45	M	52	44	
46	M	44	31	
47	M	43	25	1 claw
48	M	49	39	
49	M	41	26	
50	M	38	17	
51	F	46	27	
52	M	53	43	1 claw
53	M	47	37	
54	F	41	16	1 claw
55	M	41	21	
56	M	47	37	
57	F	41	21	
58	M	48	37	1 claw regenerated
59	F	36	13	
60	M	57	48	
61	M	45	34	
62	M	50	43	Abdomen damaged
63	F	40	20	
64	F	40	17	
65	M	43	26	
66	M	46	29	1 claw
67	F	40	17	
68	F	37	14	
69	F	40	19	
70	M	49	41	
71	F	43	23	
72	F	39	18	
73	F	38	18	
74	M	44	26	1 claw
75	M	42	23	
76	F	37	17	
77	F	37	15	
78	F	36	15	
79	F	38	15	Left telson missing

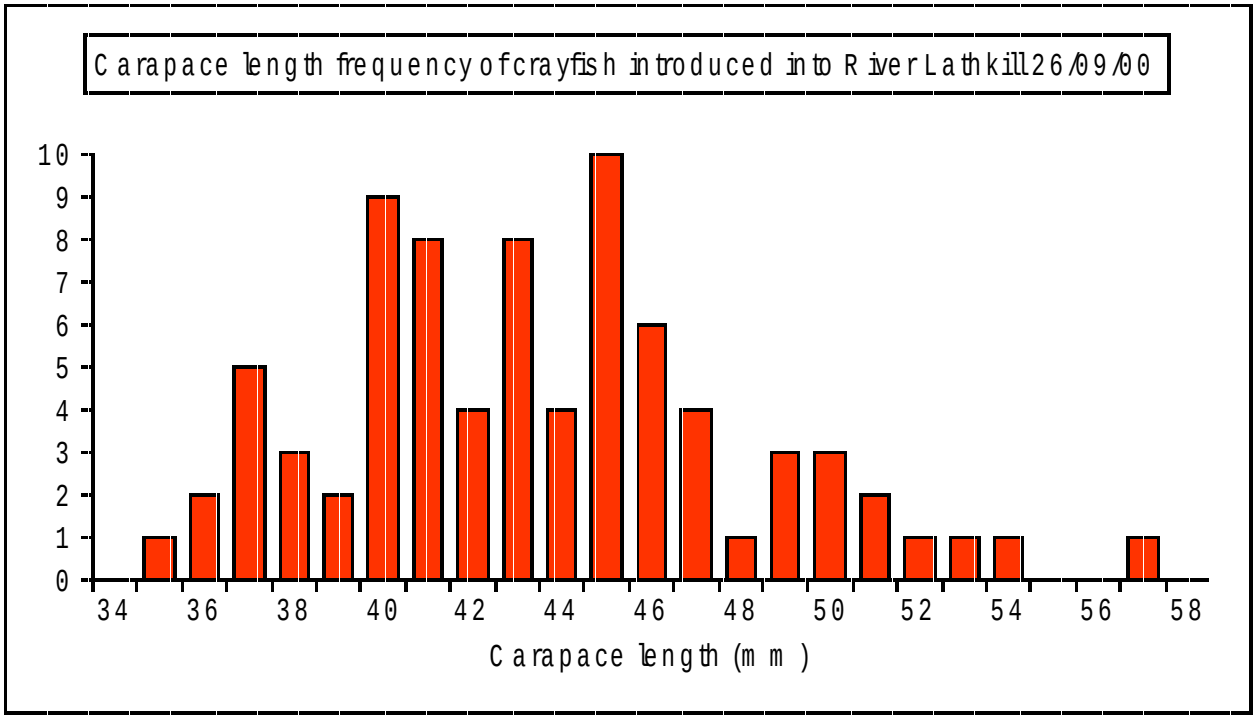

Figure 6: Carapace length frequency histogram of crayfish introduced into the River Lathkill 26/09/2000.

Appendix 4. Captive breeding of white-clawed crayfish at Castle Donington, 2002

A4.1 Introduction

The most successful method of rearing juveniles in 2001 involved the use of a flexible net hanging in a tank of slow flowing tap water (65 % survival between June and November 2001 at Castle Donington).

The aim in March-June 2002 was:

1. To construct a larger-scale version of these holding facilities (a large flexible mesh cage).

2. To introduce juvenile crayfish to the newly constructed cage, which would be placed in a concrete tank, adjacent to the River Lathkill as used earlier in this project.

3. A further aim was to observe the release time of the juveniles from the adult female crayfish very carefully so that they could be picked off at this critical time and introduced to the newly constructed cage without losses caused by the females eating their young.

A4.2 Method

A cage to hold the juvenile crayfish was constructed as follows: A flexible net was attached to a wooden framework and protected with a larger mesh net (Figure 7). Onion bags were suspended in the cage to increase the habitat available for juvenile crayfish to hide.

Between March and June 2002, 12 ovigerous adult female white-clawed crayfish were held tanks at Castle Donington where they could be easily observed. The eggs on the females hatched during this period and on 11/06/2002 juveniles were observed leaving the females. They were immediately removed from the adult females and transferred to the River Lathkill where they were placed in the newly constructed cage in the concrete tank.

Figure 7. Juveniles cage 2002.

A4.3 Results

The 12 ovigerous female crayfish held at Castle Donington between March and June 2002 yielded the following numbers of Stage 2 juveniles:

Details of juvenile taken from adult females 11/06/02

Crayfish No.	Carapace length (mm)	Weight without juveniles (g)	No. of juveniles	Comment on juveniles' behaviour
1	39	18	17	Juveniles clumped
2	37	14	29	Juveniles free swimming
3	38	15	39	Clumped and free swimming
4	37	14 (1 claw)	17	Free swimming
5	41	18	12	Free swimming
6	45	22	41	Free swimming
7	36	14	30	Clumped and free swimming
8	43	14	21	Free swimming
9	38	16	9	Clumped
10	No details		0	
11	No details		0	
12	No details		0	
Total			215 juveniles	

The 215 juvenile crayfish were taken from the females and transferred to the newly constructed cage.
Some juveniles had a tendency to clump together in a ball, normally around a piece of detritus, whereas others moved away independently (a later stage of development) when removed from the adult.
Following removal of the adults and attached juveniles, a number of juvenile crayfish (47) were also found in the tank. It is not know from which females these had been released. They have been held in aquaria for further observation.