# Interim Report for 1993 R&D Project 378

# Crayfish Conservation

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CRAYFISH CONSERVATION

NRA R&D Project 378

Interim Report for Period 01/01/93-31/12/93

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SUMMARY

- All post-1989 information concerning the distribution in Britain of the native, white-clawed crayfish (*Austropotamobius pallipes*), and the introduced species, the signal crayfish (*Pacifastacus leniusculus*), the narrowed-clawed crayfish (*Astacus leptodactylus*), the noble crayfish (*Astacus astacus*) and the red swamp crayfish (*Procambarus clarkii*), has been entered into a computerised database and has been transmitted to the ITE Biological Information Centre. Maps can now be produced in a variety of formats.

- Three mortalities of native crayfish occurred in 1993. All had classic signs of being caused by crayfish plague, but none were positively confirmed due to a lack of suitable material.

- Details of possible "no-go" areas for crayfish farming have been discussed and agreed with the NRA, JNCC and MAFF. These have been submitted by MAFF to Ministers for comment.

- Input has been made into JNCC's conservation strategy for the native crayfish and to their deliberations concerning SACs and the EC Habitats and Species Directive.

- Field work has been carried out mainly in the NRA Anglian, Southern, Thames, Welsh, and South Western Regions. Narrow-clawed crayfish have colonised a riverine system for the first time. i.e. the Stour in Suffolk. Signal crayfish have appeared in large numbers in the R. Bain in Lincolnshire and in parts of the R. Wreake catchment in the Trent basin. All known mixed populations of native and signal crayfish now appear to have been taken over entirely by signals. The signal crayfish population at Boxmoor Fishery appears to have declined in numbers, probably as a consequence of an active culling programme carried out since early 1992. An electrofishing survey of Broadmead Brook gave some indication that signal crayfish are having an adverse effect on benthic fish populations. Studies on Welsh native crayfish populations would seem to indicate that they are on a decline in some areas.

- An attempt to control the population of narrow-clawed crayfish in Tykes Water by intensive use of fyke nets has been successful in that anglers have subsequently reported far fewer problems. However, despite employing a large number of nets and taking out over 2000 crayfish, it has been estimated that only 28% of the population was removed.

- At Dinesens' crayfish farm, a 0.25 hectare site, it has only taken from pond construction and stocking in July/August 1990, until October 1993 to achieve a commercial crop (100 kg $yr^{-1}$) of crayfish for market. This annual production is only enough to provide fewer than 100 people with a traditional Scandinavian crayfish meal once a year. Thus if commercial crayfish farming is going to make an impact in Britain either much larger sites or increased intensification must be expected.

- Experiments have demonstrated that overland escapes from ponds containing crayfish can be prevented in most circumstances by use of a 0.3-m lipped barrier as long as adjacent vegetation is managed.

- Competition experiments have clearly indicated that signal crayfish predate both native and narrow-clawed crayfish, although narrow-clawed and native crayfish appear to be able to co-habit. All three species were found to be cannibalistic to some degree, particularly signals.

- Preliminary, controlled environmental impact experiments gave encouraging results and will be repeated in 1994. Signal crayfish were shown to have a dramatic impact on macrophytes and macroinvertebrates in semi-natural conditions.

- Interspecific mating experiments resulted in successful mating and egg laying between: male signal crayfish and female native or narrow-clawed crayfish; male narrow-clawed crayfish and female native or signal crayfish; and male native crayfish and female narrow-clawed crayfish, but not male native crayfish and female signal crayfish. In the majority of cases of cases the eggs failed to develop, although in some cases they are still being retained by the females and appear to be undergoing development.

- During 1993 considerable publicity has been given to the conservation of the native crayfish and the problems being caused by alien crayfish species. This has taken the form of published papers, articles in the national and local press, and comment on radio and television.

- A leaflet/poster giving details of the biology of native and alien crayfish species, including an aid to their identification, has been completed and has been printed by the NRA. This will be widely distributed during 1994.

- A survey by MAFF and an independent survey made by Nottingham University indicate that, despite farmers being encouraged to diversify into crayfish farming, the industry remains very small and that very few people are successful. The main concern is abandoned stock. This will lead to more wild populations of alien crayfish developing.

**KEY WORDS**

White-clawed (native) crayfish, signal crayfish, narrow-clawed crayfish, noble crayfish, red swamp crayfish, crayfish plague, "no-go" areas, competition, aquaculture, population density, escapes, publicity, conservation, management.

# 1. INTRODUCTION

The overall aims of the project are to assess the impact of introductions of alien crayfish and outbreaks of crayfish plague on freshwater ecosystems and to formulate a strategy for the conservation of the native species (*Austropotamobius pallipes*). Details relating to the background of the project have been given in Appendix 3 of Holdich *et al.* (1993a).

## 1.1 Specific objectives of the R&D contract

- To develop further a practicable strategy for the conservation of *A. pallipes* in England and Wales; incorporating recommendations for mechanisms by which control over introductions/escapes can be achieved and a means for monitoring strategy effectiveness.

- To investigate mechanisms for containment of populations of alien species of crayfish, the management of populations in the wild and measures for controlling the spread of crayfish plague.

- To validate and update existing information on the current distribution and status of populations of native and alien species.

- To establish, by means of field and laboratory experiments, the effects of inter-species interactions on the distribution and status of *A. pallipes* and the influence of alien species of crayfish on aquatic ecosystems.

## 1.2 Strategy for the R&D contract

- To identify, update and expand information on crayfish distribution and status in a format compatible with the existing ITE database.

- Efforts to be made to confirm causal links between alien species, and other environmental factors, and declining populations of *A. pallipes* and to prepare and test a strategy for the conservation of *A. pallipes*.

- To recommend an action programme for strategy implementation.

The following methods were agreed:

- Collation of existing distribution data, to be supplemented with survey work to verify the validity and currency of records, and to collate additional distribution and population information.

- Analysis of data on crayfish distribution and status to detect national, regional or local trends in distribution and abundance.

- Detailed survey of catchments known or suspected to have suffered from outbreaks of crayfish plague.

- Detailed survey of key sites containing populations of *A. pallipes* but unaffected by crayfish plague, introduced species or other identifiable environmental factors.

- Field and laboratory experiments to assess the effects of competition, and other environmental factors, on all species; development of practicable retention measures for crayfish "farms" where populations of alien species of crayfish already exist.

- Consultation with NRA, JNCC, MAFF and other relevant bodies to review existing and potential legislative mechanisms for the protection of *A. pallipes* and control of alien species. Consideration of the potential and success of comparable existing legislation in Europe, and elsewhere.

- Review the practicability of implementing the proposed national conservation strategy for *A. pallipes*, which has been formulated by JNCC in consultation with MAFF and NRA, and carry out iterative refinements. Test practical measures for strategy implementation and monitoring.

## 1.3 Targets

The main targets for the first 12 months (1992) were to collate the distribution data and identify plague-affected catchments. A target concerning no-go areas (see Section 2.2) for the end of 1993 was brought forward. These targets were achieved. The main targets for the second 12 months (1993) were to make proposals for "protection zones" and produce a draft conservation strategy. These are both on-going and further work has been done on them in conjunction with JNCC and MAFF. In the light of certain moderating factors (see Section 1.4) and with the agreement of the Project Leader, more attention was given to the database, the poster/leaflet, the management of alien populations, and to competition experiments.

## 1.4 Moderating factors

Despite Nottingham University's liaison with MAFF, NRA, JNCC and other interested parties in detailed consideration of "no-go" areas and JNCC's "Action Plan for the Conservation of the Native Crayfish *Austropotamobius pallipes* in the United Kingdom", only in the last month have Government Ministers been circulated with documents from MAFF asking them to consider the concept of "no-go" areas in principle. Only if Ministerial approval were forthcoming would it be worthwhile for Nottingham University to continue to consider methods for their implementation.

## 2. PROGRESS

Summarised below is information which has been included in three progress reports (Holdich *et al.*, 1993b, c, d) submitted to the NRA during the course of 1993. Additional data are included for some sections as is information relating to the last quarter of the year. Previous Progress Reports in 1992 are referenced as Holdich *et al.* (1992a, b, c) and the first Interim Report as Holdich *et al.* (1993a).

### 2.1 Distribution data

The following sections deal with work carried out to collect, collate and map the distribution of native and alien crayfish in Britain since 1989 using a variety of sources.

#### 2.1.1 Collation of records

All post-1989 records for the native, signal, narrow-clawed, noble and red swamp crayfish have been collated and entered into a Lotus 1-2-3W spreadsheet. Updating is done on a monthly basis.

Many new records have been processed in 1993, particularly for the native and signal crayfish. The post-1989 pin board map (see photographs in Holdich *et al.*, 1993a) is being kept up to date and provides a very useful means of conveying information to visitors and at conferences.

The first records for narrow-clawed crayfish inhabiting a riverine environment were received and confirmed (see Section 2.3.1). The first records for wild signal populations in Lincolnshire rivers were reported by Anglian NRA and visits were made to the site (Section 2.3.1). Southern NRA reported that a berried red swamp crayfish had been found wandering about on land. However, this is not evidence for them breeding in the wild - it is more likely to be an escapee from an aquarium.

#### 2.1.2 Record database

All records have been sent to the ITE Biological Information Centre, Monks Wood, in Lotus 1-2-3W format. These have been transferred into the ITE crayfish database. This database now holds all records for the species listed above for the period 1970-1993 inclusive. An example of the distribution of native crayfish based on ten-kilometre squares for that period is given in Figure 1. Maps for particular periods can be produced as can expanded maps giving county distribution on a one-kilometre square basis. It is hoped that, in the near future, NRA boundaries and rivers may be added to the map.

### 2.1.3 Crayfish plague

There have been three large-scale mortalities during 1993. Unfortunately, although they all exhibited classic signs of being caused by crayfish plague, MAFF was unable to confirm the cause due to lack of suitable material being sent to them.

The mortalities occurred in the Avening Brook (tributary of the R. Frome in Glos.) in the Stroud region, the R. Bradford in the Peak District, and the R. Tillingbourne near Dorking.

Little is known about the mortality in Avening Brook. The mortality in the R. Bradford is worrying as it is close to the mortalities which occurred in the R.Wye and R. Derwent in 1991 (see Holdich *et al.*, 1993a). No signal crayfish have yet been located in the area although a number of leads are being followed up. If the mortalities on the two occasions in the Peak District were due to crayfish plague, the source was not necessarily a signal crayfish implant, as the spores of the fungus may have been brought into the region on contaminated equipment or fish. The mortality in the R. Tillingbourne might have been expected as there are a number of signal crayfish farms in the area.

Figure 2 (kindly prepared for us by Dr D Alderman of MAFF) illustrates the suspected and confirmed outbreaks of crayfish plague in England and Wales from 1981 until the present day. Although many of the mortalities were fairly localised in each case the whole catchment has been highlighted as being at risk due to the virulent nature of the disease.

Alderman (1993) has summarised the history of crayfish plague outbreaks in England and Wales up until 1992. There appears to be no pattern in the outbreaks. Any attempt to restock waters previously affected by crayfish plague would therefore be premature (see Section 5.1).

## 2.2 "No-go" areas

Nottingham University were asked to provide details to the Joint Nature Conservation Committee (JNCC) and the Ministry of Agriculture, Fisheries & Food (MAFF) of the areas we thought should be considered for "no-go" status. JNCC circulated these to the Countryside Council for Wales (CCW), English Nature (EN), Scottish Natural Heritage (SNH), and the Department of Agriculture for Northern Ireland (DANI), who then circulated them to their regional offices. Comments came back and some were incorporated into our scheme. These were then discussed with MAFF at joint meetings with JNCC, NRA and Nottingham University. The final outcome is shown in Figure 3 with accompanying notes. CCW, SNH and DANI are keen that the whole of their countries should be "no-go" areas. Due to the large number of farmed and wild, alien crayfish populations in England, south of a line drawn from the Wash to the Bristol Channel, it was decided to recommend only a few native crayfish strongholds as "no-go" areas. However, control over alien crayfish ventures should still be exercised in the other areas, i.e. they should not be allowed to become "all-go"areas.

Nottingham University have given advice to JNCC about the presence of native crayfish on SSSIs to help them in their deliberations about Special Areas of Conservation (SACs) under the EC Habitats and Species Directive.

## 2.3 Field visits

### 2.3.1 Riverine

**St Catharine's Brook (Wiltshire)**

Traps (Swedish "Trappies") set by Wessex NRA (now South Western NRA) in St Catharine's Brook (part of the Bristol Avon catchment) during 1993 failed to catch any native crayfish from this former mixed native-signal population.

**Broadmead Brook (Wiltshire)**

**Introduction**

Broadmead Brook (part of the Bristol Avon catchment) is remarkable in having an apparently disease-free population of signal crayfish upstream of a population of native crayfish. The two are separated by a short stretch of brook which has no crayfish at present. Work has been carried out on the crayfish populations for a number of years by Wessex NRA and Nottingham University (Reeve, 1990; Holdich & Reeve, 1991). Despite the high density of signal crayfish reported from Broadmead Brook it has proved difficult to find conclusive evidence of any detrimental impact by this crayfish on the wider freshwater community, although no work had been done with fish. Consequently, in conjunction with Wessex NRA, an electric fishing survey was carried out at four sites in Broadmead Brook (7-8 June 1993) in an attempt to see if the two species of crayfish were having an impact on the fish populations. Two of the sites had well-established signal crayfish populations apparently free of crayfish plague, one site had a well-established population of native crayfish, and the other was free from crayfish. Table 2.1 gives details of the catches. Other details are given in Holdich *et al.* (1993d).

**Sites and methods**

Site 1 (ST 832 775) *ca* 100 m upstream of Nettleton Mill, immediately upstream of gate and stile. Well established population of native crayfish.

Site 2 (ST 818 770) *ca* 1.75 km upstream of site 1, ca 500 m upstream of Fosse Way road bridge. No crayfish present.

Site 3 (ST 805 771) *ca* 1.5 km upstream of site 2, immediately upstream of road bridge in upper West Kington. Well established population of signal crayfish.

Site 4 (ST 802 769) *ca* 350 m upstream of site 3, immediately upstream of mill-race intake above upper West Kington. Well established population of signal crayfish.

All sites were sampled by the removal method, by electric fishing. Two samples were removed by fishing upstream between two stop nets. Water quality parameters were measured using a Horiba U10 Water Quality Checker. Population data were analysed by NRA, using the population estimation methods of Carle & Strube, Seber & LeCren or Zippin where possible.

## Results

The results of the survey (Table 2.1) provide an opportunity for comparing fish populations at similar sites with or without one or other of the two crayfish species, native or signal. Water quality at the four sites was very similar (Table 2.3) as were most physical and vegetation characteristics (Table 2.2). However, such differences between the sites are probably important enough to ensure that any conclusions about the relationship between crayfish and fish populations can be tentative only.

Site 2 (the only site without crayfish) was noticeably lacking in larger stones and boulders, having large areas of fine gravel. Although the estimated mean depth of water at site 2 was comparable with that of the other sites, this estimate conceals a greater depth range: site 2 had larger areas of very shallow water with plentiful vegetation, and one large, deep pool approximately 1 m deep. These differences provide the most plausible explanations for some of the fish population differences. Site 2 had a trout population with a large density of 1+ individuals, most of which were caught in the deep pool. This site was also the only one with lamprey larvae (these animals require a deep, fine and well-oxygenated substratum) and sticklebacks (probably taking advantage of the shallow, well-vegetated back-waters).

Site 3 (one of the two sites with signal crayfish) had septic tank outfalls associated with the village. However, at the time of the visit there was no evidence of pollution other than rather more silt being present than at the other sites. This was the only site with a population of stone loach. This site also had markedly less shade in the form of directly overhanging trees. However, this site is contained between two-metre high vertical retaining walls, so it probably does not have a significantly different light input from that of the other sites.

## Discussion

Notwithstanding the differences between sites noted above, there are indications of a relationship between crayfish and fish populations in the results. Density of trout was noticeably lower in the two sites (3 & 4) with signal crayfish, compared with the site with native crayfish (site 1) and the site without crayfish (site 2), although biomass was high in site 3 because of the presence of several large trout in what was otherwise a rather small population. Comparison of the density, biomass and fork-length data (see Holdich *et al.*, 1993d) indicates that signal crayfish (sites 3 & 4) were associated with smaller populations of young (0+) trout. Bullhead density and biomass were also smaller in the two signal crayfish sites. However, sites 3 and 4 appeared to have an abundance of habitat and cover suitable for trout fry and for bullheads.

Signal crayfish populations are often much more dense than native populations in comparable waters, as is the case in Broadmead Brook, and, at sites 3 and 4, signal crayfish may be having a detrimental effect on trout fry and bullhead populations by predation, or competition for cover or food. Signal crayfish are aggressive predators, particularly on macroinvertebrates and conceivably on fish eggs or larvae, and will oust other animals from suitable cover such as cavities under stones (Reeve, 1990).

**Table 2.1 Fish population estimates**

| Site | Crayfish | Brown trout Density[2] | Brown trout Biomass[3] | Bullhead[1] Density[2] | Bullhead[1] Biomass[3] | Stone loach[1] Density[2] | Stone loach[1] Biomass[3] |
|---|---|---|---|---|---|---|---|
| 1 | natives | 0.387 (0.377-0.404) | 2.462 | 0.827 (0.728-0.927) | 3.632 | 0 | 0 |
| 2 | none | 0.447[c] (0.426-0.479) | 19.331 | 0.879[z] (0.689-1.068) | 2.794 | 0 | 0 |
| 3 | signals | 0.143 (0.136-0.157) | 14.616 | 0.157[m] | 0.557 | 0.129 (0.114-0.171) | 0.427 |
| 4 | signals | 0.227 (0.207-0.267) | 1.113 | 0.567 (0.487-0.673) | 2.284 | 0 | 0 |

Notes:
[1]not including 0+ fish
[2]$m^{-2}$ (lower and upper 95% confidence limits in parenthesis)
[3]$g\ m^{-2}$ (calculated from density estimate and mean wet mass of sample)
[c]estimated by method of Carle & Strube
[m]minimum estimate, from sum of catches
[z]estimated by method of Zippin
All other estimates by method of Seber & LeCren.

**Table 2.2 Site characteristics: physical and vegetation**

| Site | Width[1] m | Len. m | Area $m^2$ | Depth[2] m | Bare | Substrate, % area Silt[3] | Grav[4] | Pebb[5] | Cobb[6] | Vegetation, % area Shade | Emer[7] | Subm[8] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.0 | 55 | 220 | 0.25 | 5 | 5 | 30 | 55 | 5 | 90 | 2 | 0 |
| 2 | 3.8 | 50 | 190 | 0.30 | 5 | 5 | 80 | 10 | 0 | 90 | 5 | 10 |
| 3 | 2.7 | 50 | 135 | 0.20 | 5 | 10 | 20 | 60 | 5 | 5 | 0 | 5 |
| 4 | 3.0 | 50 | 150 | 0.20 | 5 | 5 | 40 | 45 | 5 | 85 | 0 | 5 |

Notes: [1,2]estimates of mean values
[3]silt and sand
[4]gravel
[5]pebbles
[6]cobbles and boulders
[7]emergent
[8]submerged (not including algae)
Len. = length

**Table 2.3 Water quality**

| Site | T/°C | Ω/mS $cm^{-1}$ | pH | $[O_2]$/mg $l^{-1}$ |
|---|---|---|---|---|
| 1 | 13 | 0.54 | 8.3 | 9.6 |
| 2 | 13 | 0.55 | 7.9 | 10.4 |
| 3 | 14 | 0.52 | 8.2 | 9.0 |
| 4 | 15 | 0.51 | 8.2 | 8.4 |

Notes: T: temperature Ω: conductivity
$[O_2]$: dissolved oxygen concentration

## Conclusions

At present it is not possible to make any more firm conclusions from the results of this single survey of what is a very small number of sites. No historical fisheries data are available for the past ten years so it is not possible to say what one would expect. Because of the characteristics of the brook it is probably not possible to improve the matching of sites with and without crayfish. Nevertheless, the survey should provide a basis for comparison in later years as the two crayfish populations change in their distribution and, as seems likely, the signal crayfish spread to areas currently having native crayfish or no crayfish.

Few studies have been undertaken to assess the impact of introduced crayfish on fish populations. However, Hepworth & Duffield (1987) showed that *Orconectes limosus* introduced into a North American reservoir stocked with rainbow trout had an impact on the growth rate of the fish. Crayfish changed the reservoir ecosystem by altering the food web and thereby reducing energy transfer to the fish.

This study highlights the problem of trying to assess the environmental impact of signal crayfish when so many other variables have to be considered.

**Owston Brook (near Melton Mowbray)**

**Introduction**

Signal crayfish were implanted into three ponds near Owston (SK 796 071) in Leicestershire about nine years ago. These ponds are spring-fed and give rise to Owston Brook. A second implant was made into another pond 0.5 km downstream soon afterwards. Owston Brook is a tributary of Gaddesby Brook which joins the R. Wreake 15 km downstream of Melton Mowbray (see Figure 4a).

The R. Wreake upstream of Melton Mowbray holds well-established populations of native crayfish (Holdich & Reeve, 1991) as do rivers in the adjacent Anglian Region, e.g. R. Chater, R. Gwash and R. Welland (Figure 4a).

**Observations**

The signal crayfish have spread downstream from the ponds (Figure 4b) and now occur in large numbers in Owston Brook itself and in Gaddesby Brook. Approximately 4000 were trapped and sold by the landowner from his ponds in 1993. The signal crayfish are moving rapidly through the catchment. Considerable television and press coverage was recently given to the situation after local residents complained about their presence (see Section 2.6.3).

The signal crayfish are fast becoming the dominant organisms in the brooks concerned. At certain points they are burrowing extensively into the banks. There is no evidence for what their food preferences are but previous work has shown that crayfish feed on macrophytes, algae, invertebrates and fish (see report on Great Ouse below). They have been seen on river banks grazing on the grass. There is evidence of fighting and attempts to eat each other as many have legs and claws missing. This probably indicates a high population density.

The population has spread downstream as far as Ashby Folville some 9 km from the implant site (Figure 4b). It is another 8 km to the R. Wreake which drains into the R. Soar after another 4 km. The signal crayfish in the upper reaches of this catchment are adjacent to the catchment of Rutland Water and thus pose a threat to an area of NRA Anglian Region as well as the Soar catchment in the NRA Severn-Trent Region.

In addition to moving downstream, the signal crayfish have moved into marshy areas, and also long distances upstream in small tributaries of Gaddesby Brook, sometimes through piped sections.

The whole catchment is very prone to flooding and this is likely to assist the spread of the signal crayfish.

### Discussion

This population of signal crayfish is the only wild population in the R. Trent catchment. The catchment is one of those being proposed as a "no-go" area for crayfish farming (see Section 2.2). The signal population may also carry crayfish plague so it is important that this population is studied in detail and that measures are considered to control it as soon as possible (see Appendix C).

## River Great Ouse (Buckinghamshire)

### Introduction

In conjunction with the University of Buckingham a study is being undertaken of a riverine signal population and covers dispersal, population dynamics, growth, recruitment, immigration, emigration, burrowing behaviour and food preferences (see Holdich *et al.*, 1993a).

Signal crayfish (100 summerlings and 40 larger individuals) introduced into the Great Ouse in 1984 at Thornborough Mill near Buckingham (SP 738 355) have dispersed 2.5 km upstream and 4 km downstream in the main channel, and 2.5 km up an adjacent tributary, Padbury Brook, formerly a native crayfish stronghold.

### Methods

Crayfish were collected from the pool subpopulation using Swedish "Trappies" covered with 4 mm mesh nets and baited with fish heads. For mark and recapture, each crayfish was marked with a unique pattern of holes made by a needle in the uropods or telson and by pleural clipping. The riffle population were sampled by means of a Serber sampler (0.25 $m^2$) in 40 random plots in a 195-$m^2$ area.

Adult burrowing behaviour was examined in artificial banks of clay constructed in aquarium tanks (200x60x30 cm). Trays (50x50x15 cm) containing clay were used to examine juvenile burrowing behaviour.

To estimate the daily ration, crayfish samples were taken at 8-hour intervals over two days. Half of each sample (approximately 50-60 crayfish) was killed immediately. The remainder were kept in an outdoor holding facility and killed when the next sample was brought back to the laboratory. Crayfish were dissected and guts removed. Their contents were extracted and before being preserved in 70% alcohol. The daily ration (DR) at each size class was calculated from the formula:

$$DR = \Sigma (W_2 - W_1)$$

where $W^2$ is the mean weight of gut contents sampled from the river at the end of the 8-h period, and $W_1$, the mean weight of gut contents of the crayfish kept in the laboratory for the same period.

### Results

Two sub-populations of signal crayfish have been studied, in a riffle and a pool section respectively. The mean CL (carapace length) and crayfish density in both subpopulations reflects the pattern of recruitment and growth, with larger individuals occupying the pool environment as was found last year (see Holdich *et al.*, 1993a). In June, an average density of 14.9 $m^{-2}$ was recorded for the riffle section. This high density reflects the recruitment of juveniles to the population. However, the density declined rapidly in Autumn, probably due to predation and cannibalism.

Signal crayfish have been found to consume approximately equal amounts of plant and animal food, except that newly independent juveniles feed mainly on animal material. The most important animal elements of the diet appear to be Chironomidae, Ephemeroptera and other crayfish. Large crayfish (45 mm CL) also eat fish. Crayfish >33 mm CL, especially those >45 mm CL, ate considerable numbers of smaller crayfish. The mean individual daily ration for signal crayfish in July 1993 was estimated for different sized individuals as 0.005 g (> 13 mm CL), 0.044 g (18-33 mm CL), 0.283 g (33.1-45 mm CL) and 1.104 g (>45 mm CL). The diel peak foraging time in summer was between 16.30 h and 00.30 h.

Evidence of burrowing into the river banks is extensive although this has not been quantified yet. Where there is a high density there is some evidence of collapse of the river banks. In the laboratory, crayfish of <50 mm CL appear to burrow more often than those of >50 mm CL. Burrows are usually straight with a single opening.

### Discussion

This is the only detailed study being carried out on a riverine population of signal crayfish at the present time. The results clearly show that subpopulations of different age classes develop in different habitats and that they are added to by recruitment at specific times of the year. The population is spreading both downstream and upstream with a mean speed of dispersal of approximately 1 km per year. This is similar to that reported for Broadmead Brook (Reeve, 1990). Dispersal there tended to occur in fits and starts as the population built up in numbers in particular localities and then expanded.

From the density of crayfish present and the amount of animal matter they consume it seems probable that the signal crayfish are having an impact on the macroinvertebrate population, particularly the Chironomidae, Ephemeroptera and other crayfish. This may result in less food being available for the fish.

Signal crayfish in the Great Ouse burrow extensively into the banks and river bed. In the laboratory, at least, burrows have a single opening and larger crayfish do not appear to burrow as often as smaller ones. It is thought that it may be difficult for the larger crayfish to construct burrows due to the size of their chelae. Large crayfish do not appear to need shelter from potential predators as much as do small crayfish. They have frequently been seen moving about on the river bed during daylight hours. In 1994 field studies will be made to estimate the amount of soil excavated by the crayfish. The amount is likely to be considerable as new burrows are constructed when the water level changes. Interestingly, no reports of the burrowing activities of signal crayfish are known from other countries.

### Dick Brook (Worcestershire)

Dick Brook, a tributary of the R. Severn to the south of the Wyre Forest (SO 812 667), contained a mixed population of native and signal crayfish in 1990. An extensive search in 1993 failed to reveal any natives although a number of signals were caught (Holdich *et al.*, 1993d). The density of the signals did not appear to have diminished. Although not conclusive this site appears to provide further evidence of the ability of disease-free signal crayfish to replace native crayfish in the wild.

### R. Stour (Suffolk)

The R. Stour, in East Anglia is currently the only river catchment in Britain for which there are records for native, signal and narrow-clawed crayfish. However, although the pre-1990 records for native crayfish are probably accurate, those for post-1989 are suspect as there are recent confirmed records for narrow-clawed crayfish in the river. Although signals are present in the catchment none have been reported from the wild. It seems highly likely that the narrow-clawed crayfish originated from an implant made in 1980 into a lake at Great Cornard (TL 901 405). No measures were ever taken to prevent escapes. All the narrow-clawed crayfish found in the river to date have been in the vicinity of Flatford Mill, 30 km downstream of the implant, and close to the tidal part of the river.

The records for the R. Stour are the first for narrow-clawed crayfish in a riverine environment in Britain.

### R. Bain and R. Ancholme (Lincolnshire)

The River Bain is a chalk stream tributary of the R. Witham. 216 signal crayfish were collected by the NRA at Biscathorpe Ford (TF 232 849) on 13 Sept. 1993, providing the first record of a breeding population of alien crayfish in the wild in Lincolnshire. Nottingham University visited the site and advised the Regional NRA on purchase of traps and survey methods. The distribution and density of the signal population are currently under investigation and methods of containment are due to be discussed between interested parties (e.g. NRA, English Nature, Nottingham University). This population poses a major threat to the chalk streams of the Lincolnshire Wolds and the upper reaches of the R. Witham which is traditionally an area where good populations of native crayfish occur.

Two single specimens of signal crayfish were reported by NRA Anglian Region at Cadney Intake (TA 001 029) and Broughton Bridge (SE 985 105) on the R. Ancholme in north Lincolnshire. Further developments will be monitored.

### 2.3.2 Lacustrine

**Wasing Lake (Berkshire)**

**Introduction**

Records held at Nottingham University show that this 0.3-ha lake (SU 588 639) near Aldermaston used to contain native crayfish. It was stocked with signal crayfish some time in the early 1980s and by 1985 native crayfish were no longer in evidence. Signal crayfish have been harvested for market, the last trapping having taken place in 1988.

**Method**

The lake was completely drained in April 1993 and all visible crayfish were collected by hand by three people over a 6-hour period.

**Results**

The sex ratio of collected crayfish was 1:1 with a size range of 15-75 mm CL, including berried females. However, the total number of crayfish was only 269, i.e. a density of only 0.07 $m^{-2}$. Some 45% of individuals were damaged, probably indicating fighting due to overcrowding. Alternatively attempted predation by fish and birds may have been the cause.

**Discussion**

The evidence would seem to indicate that more crayfish were present than were collected. There may be a parallel in Wasing Lake with a situation which occurred at Hauxton Fishery (Cambs) (Reeve, 1990). Here the farmer was of the impression that he had removed all the signal crayfish from his carp pond by seine netting and draining followed by hand removal in 1986. After a second seine netting and draining exercise in 1987 a similar number of signal crayfish (350) were obtained to that found in 1986. It was also found that crayfish were burrowing extensively into the banks, sometimes at a density of 20 burrows $m^{-2}$ (Reeve, 1990). Upon draining, many crayfish remained in their burrows resulting in an underestimate of the population. The same effect may well have happened at Wasing Lake although no mention of burrows was made by the crayfish collectors. It would be worthwhile to carry out a trapping exercise to ascertain whether or not all the crayfish really were removed.

This highlights one of the problems of trying to remove signal crayfish from situations in which they can burrow.

## Tykes Water (Hertfordshire)

### Introduction

Details of the work done on the narrow-clawed crayfish (*Astacus leptodactylus*) population in Tykes Water have been given in Holdich *et al.* (1993a, b, c). After an initial survey in October 1992 using Swedish "Trappies", the NRA provided additional funds so that a detailed trapping exercise could be carried out; the aim being to see whether the population could be reduced to a level where it would not be a nuisance to the anglers.

### Method

In December 1992/January 1993 an attempt was made to remove the trappable part of the population from the lake using 70 fyke nets over a five-week period. Further trappings were made in March/April and May 1993. On the latter occasion Swedish "Trappies" and spring-type traps were also employed.

### Results

The catch data are shown in Table 2.4. Surprisingly 88% males were found in the catch compared with the survey in October 1992 (see Holdich *et al.*, 1992a) which had yielded 71% females. The effect that removal might have on smaller cohorts is the subject of a detailed and comprehensive computer analysis which will be undertaken in 1994. The large number trapped, i.e. 2440 males and 319 females, despite appearing to have a large effect on the population, was calculated to be only 28% of the population. Although the CPUE was small it did decline significantly over the study period indicating that the fyke nets were having a significant effect on the population. The study highlighted the invasive nature of this species and its ability to build up large populations in a relatively short period of time.

In March/April 1993, the sex ratio of a further 600 crayfish trapped using fyke nets was 50:50. However in May 1993 a further catch of 2774 crayfish in fyke nets (unbaited as usual) yielded 54% females whereas the catch from Swedish baited crayfish traps (Trappies and spring-type traps) over the same period yielded 238 crayfish with only 32% females. This indicates that the sexes have different habits and preferences over the annual cycle

The outlet from Tykes Water flows 8 km before entering the R. Colne. An investigation of this area showed that narrow-clawed crayfish had migrated downstream into the stream and were present at low density. There was no evidence of them entering the R. Colne. Attempts to measure immigration to Tykes Water using a bag net over the inlet for two weeks in May 1993 yielded only one crayfish.

**Table 2.4 Catch data for Tykes Water**

| Catch no. | No of days set | No. of nets set | ♂ crayfish | ♀ crayfish | Total | CPUE |
|---|---|---|---|---|---|---|
| 1 | 2 | 69 | 285 | 39 | 324 | 2.35 |
| 2 | 5 | 65 | 525 | 39 | 564 | 1.74 |
| 3 | 8 | 70 | 620 | 52 | 672 | 1.20 |
| 4 | 9 | 70 | 400 | 90 | 490 | 0.78 |
| 5 | 4 | 70 | 209 | 23 | 232 | 0.82 |
| 6 | 4 | 70 | 223 | 36 | 259 | 0.92 |
| 7 | 4 | 70 | 178 | 40 | 218 | 0.78 |
| Totals | 36 | 484 | 2440 | 319 | 2759 | |

**Discussion**

Despite the fact that only 28% of the trappable part of the narrow-clawed crayfish population appears to have been removed during this exercise, the anglers at Tykes Water considered the exercise a satisfactory solution to their problem during 1993. During the year they purchased their own fyke nets to keep the population of crayfish down to a satisfactory level to prevent excessive interference with their angling. It remains to be seen whether or not the population responds to the culling by undergoing faster growth of smaller cohorts. If this turns out to be the case then the situation could revert to the pre-1993 situation in 1994 (see discussion under Section 2.3.2 Boxmoor Fishery). Further monitoring of the situation will be carried out from April 1994.

**Serpentine (London)**

**Introduction**

A population of narrow-clawed crayfish has been known to exist in the Serpentine since 1991. Unsuccessful attempts were made by the Thames Angling Preservation Society (TAPS) in conjunction with NRA Thames Region to investigate this population by seine netting in 1992. Following this, trapping was carried out by one of the boat hire staff on the lake using shrimp traps in the summer of 1993 and this was publicised in the Daily Mail (11 Sept. 1993) which also reported that he sold his catch in Paris. It is not thought that either of the above exercises had any appreciable impact on the population.

### Method

Since October 1993 a more serious attempt has been made to remove some crayfish from the lake using fyke nets. Nottingham University have made four trips to the site and have access to the trapping data.

### Results

Twenty-eight fyke nets were set for seven days on two occasions around the perimeter of the island in the lake during initial removal. The yield was 45 kg (833 crayfish) on the first occasion and 36 kg (604 crayfish) on the second. Lengths and weights of a representative sample were taken and showed that the crayfish from the Serpentine were more than twice the weight (mean 55 g) of those initially trapped at Tykes Water (mean 25 g). However, they did not show such a difference in length (mean carapace length 58 mm and 45 mm respectively).

### Discussion

Holdich *et al.* (1993b) reported that the catch per unit effort (CPUE) in Tykes Water varied between 2.35 and 0.78 crayfish per net day whereas the CPUE in the Serpentine was between 4.24 and 3.08 crayfish per net day. In addition the Serpentine covers 16.3 ha whereas Tykes Water covers only 1.9 ha, and thus the population of crayfish in the Serpentine is considerably larger, and probably equates with that in Aldenham Reservoir, north of Tykes Water. These are the largest known populations of narrow-clawed crayfish in Britain.

Larger numbers of fyke nets are currently being employed by commercial netsmen (contracted to the Royal Parks) for trapping this lake with consequent higher catches. The results continue to be monitored by Nottingham University.

## Boxmoor Fishery

### Introduction

Details of this lake have been given in Holdich *et al.* (1993a). The main aims of the study are to assess the status of the mixed native/signal population, to gather information on the population biology of the signal crayfish, and to see whether or not removal had an effect on the signal crayfish population.

For management purposes, it is important to know the effectiveness of traps over different time periods, i.e. for the best catch should traps be lifted after one night or do they catch more if left down longer or, do they progressively lose their catch? This was tested over a 3-day period.

**Methods**

On each visit traps (Swedish "Trappies") are set at regular intervals around the lake, the number employed usually being 50. These are left down overnight (approx. 1600 h to 08.00 h) and then the catch is removed, counted, sexed, weighed and measured. One a year the trapping exercise takes place just before a seine-netting exercise. This is carried out by Thames Region NRA in order to assess the status of the grass carp population in the lake. Crayfish are caught co-incidentally, but the numbers netted are dependent upon whether or not the net touches the bed of the lake and collects weed and sediment. Since February 1992 all crayfish caught have been removed and have been either eaten, sold or used in experiments at Nottingham.

To test the effectiveness of the traps they were left down with their catch for three days and checked each day. Individuals present on each day were given a particular mark using "Tippex".

**Results**

Table 2.5 summarises all the catch data for Boxmoor Fishery from September 1993 until February 1994.

Although initial catches of native and signal crayfish were relatively low but similar, the signal crayfish catches started to increase dramatically in 1991. Although native numbers were relatively high on trip nos. 11-15 they dropped off rapidly after that and none were caught after the seine-netting exercise in February 1992.

The CPUE for signal crayfish varied considerably, although it was usually greatest in the summer and autumn periods, e.g. trip nos 12, 13, 14, 19, 20, 24b (Table 2.5) when water temperatures were higher. However, some large catches have also been made in traps in winter, e.g. trip. no. 22a, and also when seine nets were used, e.g. trip nos 18b and 22b (Table 2.5).

After trip no.18 in February 1992 a decision was made to remove all signals caught in future in the hope that this might reduce the pressure on any remaining natives and also reduce the stock of signals. By removing large numbers of berried females (over 50% of the females usually had eggs in February catches) it was hoped that this would reduce recruitment to the signal population.

However, in February 1993, the largest number ever caught in traps for a winter month was recorded (trip no. 22a). Numbers were also very high in September 1993 when the trap efficiency exercise was carried out. In particular traps 1-18 (out of 50) caught 209 signal crayfish on the first trapping.

In February 1994 a trapping and seine netting exercise was carried out (trip no. 26). and only 47 signals were caught in the traps and 79 in the seine.

The results for the 3-day trap effectiveness study are shown in the bottom part of Table 2.5 as horizontal rows 23-24b. It was found that there was considerable movement of crayfish in and out of the traps, and that after an initial heavy catch in some traps there was a decline with time (see Holdich *et al.*, 1993d). Indeed in traps 1-18 the decline was from 210 crayfish trapped on Day 1 to 142 present on Day 2 to only 129 present on Day 3. However, overall there was little difference in the numbers caught on Day 2 (trip no. 24b) and Day 3 (trip no. 25b). Unfortunately, it was not possible to sample all the traps on Day 1 and only 18 were emptied.

**Table 2.5 Catch data from Boxmoor Fishery**

| Trip no. | Date | No. traps | ♂ S | ♀ S | ♂ N | ♀ N | Total | Ratio S:N | Per trap |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 04/09/90 | 40 | 18 | 13 | 10 | 14 | 55 | 1.3:1 | 1.37 |
| 2 | 15/10/90 | 40 | 36 | 2 | 4 | 1 | 43 | 7.6:1 | 1.07 |
| 3 | 30/10/90 | 40 | 11 | 2 | 4 | 2 | 19 | 2.2:1 | 0.47 |
| 4 | 11/11/90 | 40 | 4 | 2 | 11 | 0 | 17 | 0.5:1 | 0.42 |
| 5 | 25/11/90 | 42 | 6 | 0 | 1 | 0 | 7 | 6.0:1 | 0.24 |
| 6a | 03/03/91 | 45 | 6 | 2 | 0 | 2 | 10 | 4.0:1 | 0.22 |
| 6b | 03/03/91 | seine | 14 | 9 | 7 | 9 | 39 | 1.4:1 | |
| 7 | 01/04/91 | 42 | 140 | 0 | 3 | 0 | 17 | 4.7:1 | 0.40 |
| 8 | 29/04/91 | 50 | 18 | 0 | 0 | 1 | 19 | 18.0:1 | 0.38 |
| 9 | 20/05/91 | 50 | 4 | 1 | 0 | 0 | 5 | | 0.10 |
| 10 | 10/06/91 | 50 | 43 | 23 | 2 | 2 | 70 | 16.5:1 | 1.40 |
| 11 | 17/06/91 | 50 | 51 | 25 | 13 | 7 | 106 | 2.5:1 | 2.12 |
| 12 | 09/07/91 | 50 | 119 | 102 | 14 | 17 | 252 | 7.2:1 | 5.04 |
| 13 | 13/08/91 | 50 | 185 | 118 | 16 | 15 | 335 | 9.5:1 | 6.70 |
| 14 | 09/09/91 | 51 | 110 | 104 | 8 | 5 | 227 | 17.8:1 | 4.45 |
| 15 | 24/09/91 | 51 | 123 | 113 | 12 | 14 | 262 | 9.0:1 | 5.13 |
| 16 | 21/10/91 | 51 | 58 | 2 | 1 | 1 | 63 | 30.5:1 | 1.23 |
| 17 | 10/11/91 | 51 | 83 | 21 | 4 | 0 | 108 | 26.0:1 | 2.10 |
| 18a | 09/02/92 | 51 | 17 | 8 | 0 | 0 | 25 | | 0.49 |
| 18b | 09/02/92 | seine | 347 | 225 | 4 | 4 | 580 | 71.5:1 | |
| 19 | 20/07/92 | 50 | 85 | 79 | 0 | 0 | 164 | | 3.28 |
| 20 | 11/10/92 | 49 | 121 | 18 | 0 | 0 | 139 | | 2.80 |
| 21 | 30/11/92 | 48 | 63 | 31 | 0 | 0 | 94 | | 1.96 |
| 22a | 14/02/93 | 47 | 130 | 82 | 0 | 0 | 212 | | 4.50 |
| 22b | 14/02/93 | seine | 172 | 172 | 0 | 0 | 344 | | |
| 23 | 13/09/93 | 18 | 69 | 140 | 0 | 0 | 209 | | 11.60 |
| 24a | 14/09/93 | 18 | 37 | 73 | 0 | 0 | 142 | | 7.90 |
| 24b | 14/09/93 | 50 | 123 | 170 | 0 | 0 | 293 | | 5.86 |
| 25a | 15/09/93 | 18 | 43 | 87 | 0 | 0 | 130 | | 7.20 |
| 25b | 15/09/93 | 50 | 97 | 183 | 0 | 0 | 279 | | 5.58 |
| 26a | 13/02/94 | 50 | 18 | 11 | 0 | 0 | 29 | | 0.58 |
| 26b | 13/02/94 | seine | 46 | 34 | 0 | 0 | 79 | | |

Notes: S=signal, N=native

#### Discussion

It is highly likely that the population of native crayfish has now been eliminated as none were caught in the February 1993 seine netting and trapping exercise, or later in the year. Signal crayfish from Boxmoor were used for the competition experiments at Nottingham (see Section 2.4) and no outbreak of crayfish plague occurred. The natives may have been finally eliminated by predation from signals (see Section 2.4) and/or by fish and waterfowl predation.

The study has shown that initially the number of signal crayfish in the lake was not affected by the removal of a large number from February 1991. Indeed the catch per trap in February 1992 and September 1993 was little different from that in September 1991. It would appear that removing a large number of potential juveniles (i.e. in the form of berried females) plus the larger trappable individuals in the population, has allowed the one to two year old signals individuals to grow rapidly. All of the crayfish caught in September 1993 were removed before breeding had started.

The trap efficiency exercise showed that in unmodified Swedish "Trappies" there is considerable movement in and out of the traps. It would appear that in order to maximise yield it is better to empty the traps after one night rather than leaving them for a few days which is the current practice.

Momot (1991) considers that crayfish populations inhabiting temperate waters respond to an increase in culling rates mainly through an alteration of age-specific mortality rates. Mature males would appear to suppress recruitment of young crayfish. Momot suggests that there is a self-regulatory process which is the result of dynamic intra-life stage interactions within food-limiting systems. Momot (1993) found that when he subjected a Canadian lake population of *Orconectes virilis* to heavy culling, which removed the larger individuals from the population, then this allowed pre-recruitment survival rates to increase. The result was an expansion in numbers despite increased trapping pressure. This appears to be what initially happened with the Boxmoor signal population but, because the berried females were also removed (Momot allowed his to release their young before capture) then this also reduced recruitment, resulting in a decline in numbers, as shown by the February 1994 data. However, too much must not be read into the February 1994 result as other factors such as cold weather and the efficiency of the seine net may have played a part in the low number caught. Further work will be carried out to see if the population continues to decline.

### 2.3.3 Wales

#### Introduction

A series of visits were made to Wales and its borders during July and August, 1992. These were briefly reported on in Holdich *et al.* (1993a) and more fully in Holdich (1993d). The work reported on was done partly under a contract from the Countryside Council for Wales (CCW) and partly for the current NRA contract. Two workers associated with the field centre at Newbridge-on-Wye assisted with some of the survey work. They were employed on a separate CCW contract to Dr F. Slater to determine the outcome of native crayfish implants made by Foster in the 1980s (Foster, 1990).

The aims of the study were four-fold: 1. to confirm the status of native and alien crayfish in the catchments of the R. Severn, R. Teme, R. Wye, R. Usk and sites in Pembrokeshire, 2. to determine the status of implants of native crayfish, 3. to determine the need to establish "no-go" areas in Welsh catchments, 4. to obtain material for an investigation into the genetic diversity of native crayfish populations in Wales. In addition, a literature survey was carried out on previous crayfish studies in Wales.

**Methods**

Field study - a total of 39 sites were sampled in the catchments of the R. Severn, R. Teme, R. Wye, R. Usk and selected streams in Pembrokeshire. At most sites hand-searching was carried out by at least three people for at least 30 minutes, i.e. 1.5 man-hours. At some sites Swedish "Trappies" were also left down overnight.

Genetic study - see separate section.

**Results**

The field work confirmed the presence of many native crayfish population, particularly in the R. Wye and Usk catchments, but, on the other hand, native crayfish were not found at many sites where they had previously been found, despite intensive surveys. No sign of any of Foster's implants could be found.

A number of signal crayfish populations were confirmed. It was apparent that no attempts were being made to stop their escape into the wild.

Native crayfish appear to have been eliminated from the R. Camlad by crayfish plague.

Detailed maps were produced of pre-1990 and post-1989 crayfish distribution in Wales (see Holdich, 1993d).

**Discussion**

Compared with the situation prior to 1990, there are fewer native crayfish records now in existence for Wales. This would appear to be largely due to man's activities, i.e. pollution, mining, waterway management schemes (Roscoe, 1986; Foster, 1990), although crayfish plague has also played a part. Slater (pers. comm., 1993) reported that it is now difficult to find native crayfish at many sites on the R. Wye where they were once common.

It was recommended (see Holdich, 1993d) that the whole of Wales be considered for "no-go" status in the light of the fragile nature of the populations, as the spread of signal crayfish can only exacerbate the problem being caused by man's activities.

The majority of native crayfish records in Wales are restricted to the borderlands. The majority of waters are in geologically old areas and tend to tend to be "soft" and unsuitable for native crayfish. However, there are some waters in these areas of Wales where it is thought the native crayfish could survive. CCW are considering whether they should allow native crayfish to be transferred from one site to another for stocking purposes or, if native crayfish populations proved to be genetically unique, they should maintain biodiversity by keeping stocks separate. None of Foster's (1990) implants appears to have been successful, but in many cases they had been put into unsuitable waters. In some ways this lack of success is a blessing as no note was taken of the genetic nature of the stock.

**Genetic study**

As this was specifically part of the CCW contract, the report by Holdich (1993d) is only briefly summarised here.

In conjunction with the Department of Genetics at Nottingham University a study of polymorphic minisatellites ("fingerprints") was planned. So as not to waste native crayfish material, it was decided to test the method with signal crayfish first.

Initial DNA preparation was by conventional phenol/chloroform extraction. The initial product seemed of high molecular weight, but on incubation it degraded into a mass of small fragments. Despite trying a wide variety of techniques to try and correct this problem, all were equally unproductive. It seemed as though there were nucleases present in the samples that could not be removed, and these were breaking up the DNA before it could be stabilised. Cutting the DNA with restriction enzymes was attempted. The digests were then subjected to electrophoresis and Southern blotted before probing with cloned minisatellites. Nothing other than a smear across the entire molecular weight range was found. Other techniques, including the Polymerase Chain Reaction (PCR) to investigate the mitochondrial gene for cytochrome b was tried, but this was not successful.

It appears more difficult to produce DNA genetic fingerprints for crayfish than for any other species tried before at Nottingham University (e.g. insects, molluscs and birds). A literature review failed to produce a single reference to the DNA fingerprinting of crayfish nuclear genomic DNA. It was concluded that without much more time and money the problem could not be resolved. Consequently, material from native crayfish was never analysed.

### 2.3.4 Crayfish farming

**Dinesens' crayfish farm (River Test, Hampshire)**

**Adult sampling**

**Introduction**

Monitoring growth and production on crayfish farms gives an insight into the crayfish farming industry as well as providing some basic zoological information on the dynamics of crayfish populations. Thus, detailed studies at Dinesens' crayfish farm using signal crayfish were continued in 1993 (see also Holdich *et al.*, 1993a, b, c), and a broader picture was established by combining information from this site with the information in the replies to the crayfish farm questionnaire described in Section 2.7.

**Methods**

Work at this site consisted of two major periods of study of the pond populations in May/June 1993 and October 1993, as well as occasional visits on average at monthly intervals to monitor the situation and make sure experiments were running correctly.

In May/June 1993, the mark-recapture technique was used to estimate the populations of four ponds (1, 2, 3 and 4). Fyke nets were used to capture the crayfish, and pleural clipping was used to mark them.

**Results**

Average weights were calculated from the large samples taken and total weights from the population estimate (Table 2.4). These were taken as the starting positions for the 1993 season.

**Table 2.6 Stock data at Dinesens' May/June 1993**

| Pond no. | Population estimate | Average weight (g) | Total weight (kg) |
|---|---|---|---|
| 1 | 1833 | 35.7 | 65.4 |
| 2 | 2063 | 11.9 | 24.5 |
| 3 | 480 | 27.9 | 13.3 |
| 4 | 693 | 44.0 | 30.5 |

The surface area of each of the ponds is 650 $m^2$ (100 m x 6.5 m). Thus the density of crayfish in the ponds ranges from approximately 1 to 3 crayfish $m^{-2}$. This was considered a low figure for a farming situation, so no plans were made to remove any of the stock until the autumn.

It was discovered that the population in each pond could be divided to a greater or lesser extent into at least two cohorts, those below 12 g and those above 30 g. The 12 g cohort was probably last year's juveniles and was thought not to be as well sampled by the fyke nets as the larger crayfish.

The presence of the two cohorts is demonstrated by the weight frequency histogram in Figure 5. Experiments were conducted on site to see if these two cohorts grew and survived better when they were mixed or when they were isolated from each other. When the results of these experiments have been analyzed they may shed light on the effect of removing a larger sized cohort from a crayfish population which could have implications that may be applicable to crayfish populations in general and not just the farming situation.

Population estimates by a mark-recapture technique were repeated in October 1993 and those crayfish with a total length greater than 100 mm were sold by the owners. The data collected over the last two years enabled a crayfish production figure of 400 kg $ha^{-1}$ of water surface to be estimated for this type of farm. This figure could provide a benchmark for assessment of other farms.

### Discussion

Although this farm appears to have been successful in terms of growth of the population and production, the production figure (100 kg per annum) must be viewed in perspective. The amount produced is only enough to provide a traditional Scandinavian meal of crayfish for fewer than 100 people on one occasion per annum, i.e. 10 crayfish per person. Consequently it has virtually no market impact and one must expect much larger units to be forthcoming if entrepreneurs take up the commercial challenge. The only farm on one single site working on a commercial scale in Britain at present is Morghew Farm at Tenterden in Kent.

## Juvenile sampling

### Introduction

Any assessment of the development of a crayfish population needs some estimate of recruitment. Numbers of ovigerous females and the size of an average brood can be calculated to give some idea of the potential recruitment. Some idea of the actual recruitment can be obtained from sampling juveniles. Female crayfish overwinter with their eggs and then in late spring the eggs hatch into Stage 1 juveniles. After 1-2 weeks these moult into Stage 2 juveniles. Stage 2 juveniles initially stay with the mother but gradually become independent. After the moult to Stage 3 the juveniles are fully formed with the exception of the secondary sexual characters (Holdich, 1993b). Juvenile stages are particularly prone to mortality due to moult failure and predation by insect larvae, fish and other crayfish.

There are few published accounts of reliable, quantitative methods for assessing juvenile abundance. This is usually done by sweep-netting through marginal vegetation or by laying down "onion bags" as artificial hides to attract juveniles. A standard Freshwater Biological Association (FBA) air-lift sampler offers a method of sampling a known area of pond bed.

### Method

At Dinesens' crayfish farm, Ponds 5 and 6 (area 184 $m^2$ each) were cleared of all trappable crayfish by successive use of fyke nets in November 1992, i.e. until no crayfish were caught. A known number of ovigerous females were introduced into the ponds. When they had released their offspring, the females were recaptured, again by successive use of fyke nets, and removed. The number of females recaptured from each pond was multiplied by an average figure for the number of eggs per female to give a figure for potential recruitment to the ponds in autumn 1992. From May 1993 onwards the juveniles were sampled approximately monthly using a standard FBA air-lift sampler. The sampler was operated by a standard procedure as outlined in the FBA Occasional Publication No. 22 (1983). The source of air was from compressed air cylinders. The four cylinders available allowed 16 samples to be taken per visit to the site. As the area of the base of the sampler was 0.0415 $m^2$, an area of 0.332 $m^2$ of each pond could be sampled on each visit.

## Results

The distribution of juveniles in the ponds was clearly biased towards the edge of the pond on the first visit (Table 2.7). This was compensated for by treating the ponds as two areas, "middle" and "edge", to calculate the estimated juvenile population of the ponds. In subsequent samples no such bias became apparent so the area sampled was treated as a random sample of the horizontal pond area.

**Table 2.7 Summary of air-lift results**

| Date | Pond 5 Carapace length (mm) | Pond 5 Juvenile pop. estimate | Pond 6 Carapace length (mm) | Pond 6 Juvenile pop. estimate |
|---|---|---|---|---|
| November 1992 | Eggs on ♀ | 47 000 | Eggs on ♀ | 69 000 |
| 15.05.93 | Juvs on ♀ | | Juvs on ♀ | |
| 25.05.93 | Stage 2 | 26 000 | Stage 2 | 12 000 |
| 18.06.93 | 7.0 | 12 000 | 7.7 | 9 000 |
| 05.07.93 | 9.3 | 4 000 | 9.2 | 14 000 |
| 05.08.93 | 10.7 | 13 000 | 10.3 | 9 000 |
| 08.09.93 | 12.6 | 17 000 | 13.9 | 17 000 |
| 13.10.93 | 15.7 | 11 000 | 14.4 | 5 000 |
| 06.12.93 | 14.2 | 11 000 | 15.6 | 8 000 |
| 11.02.94 | 14.6 | 9 000 | 15.8 | 15 000 |

## Discussion

It is hoped that the increasing carapace length of these crayfish (Table 2.7) over the winter months will show that the smallest cohort (mean weight, 12 g) visible in the May/June 1993 results of Dinesens' Ponds 1 to 4 are in fact derived from the juveniles the previous year. The results may also indicate whether the second smallest cohort (mean weight, 30 g) could have been derived from the previous year's juveniles or whether they are more likely to be a year older.

These are the first quantitative data on juvenile crayfish density to be obtained in Britain. They indicate that despite the introduction of different numbers of ovigerous females into the two ponds, the juveniles tended towards a similar density. The average density over the period of air-lift sampling in 1993 was 12 000 juveniles per pond, which is equivalent to a density of 65 juveniles $m^{-2}$.

## Design of barrier to prevent crayfish escapes

### Introduction

It has been noted that very few crayfish farmers take measures to protect their stock on crayfish farms. If they are culturing an alien species then they are expected to do so under the terms of the Wildlife and Countryside Act 1981, particularly if the species is listed on Schedule 9 (see Holdich *et al.*, 1992a). It is also important that stock is prevented from escaping if it harbours crayfish plague.

Protection can take the form of a barrier around the site to prevent escapes across land, netting to prevent individuals being taken by birds (and perhaps dropped elsewhere), and netting across inlet and outlet pipes. Covering inlet and outlet pipes can cause problems due to a build up of trapped materials, which may result in flooding if it involves the outlet pipe. Covering such pipes with netting is unlikely to prevent juveniles escaping, and is likely to be ineffective against stopping the escape of spores of the crayfish plague fungus. Ideally, crayfish farm sites should have no outflow of water.

An experiment was carried out in Sept. 1993 to assess the effectiveness of a barrier which had been put in place at the Dinesens' site.

### Materials and methods

The series of ponds on the Dinesens' crayfish farm site is surrounded by a 300 mm high (above ground level) metal barrier with an 80 mm inwardly protruding lip (see Holdich *et al.*, 1993d). A series of simulated escapes (5 replicates) were carried out using 50 crayfish (40-60 mm CL) placed on wet grass against the fence.

Corrugated plastic arenas (1.8 m in circumference) 75 mm, 150 mm and 300 mm in height, without a lip, were used for similar simulated escapes.

### Results

Even when they piled on top of one another (see Holdich *et al.*, 1993d) the crayfish were unable to escape across the lipped barrier. Crayfish were found to escape from the arenas if they were below 150 mm in height, by climbing on each other's backs.

### Discussion

Although the 300 mm lipped metal barrier and the 300 mm unlipped plastic barrier worked equally well, the former is stronger and consequently less prone to damage from humans and machinery. An important factor in the success of such barriers is control of the vegetation, particularly on the inside, to prevent crayfish climbing over it.

## 2.4 Competition experiments

### 2.4.1 Adult competition

**Introduction**

It is difficult to assess the impact that signal crayfish are having on the freshwater environment (see Section 2.5), particularly on other crayfish species, except that caused by crayfish plague (see Section 2.1.3). In order to show possible effects of the two main alien species occurring in the wild in Britain, i.e. signal and narrow-clawed crayfish, on the native crayfish, there was a need to carry out large-scale experiments under controlled conditions. The Department of Life Science at The University of Nottingham possesses a series of large and medium-sized concrete tanks which were made available for such an experiment during 1993.

**Materials and methods**

Native crayfish were obtained under licence from English Nature from Ensor's Pool (see Holdich *et al.*, 1993a), disease-free signal crayfish from Boxmoor Fishery (see Section 2.3.2) and narrow-clawed crayfish from Tykes Water (see Section 2.3.2). All specimens were kept in separate tanks during the early part of 1993 and only complete (i.e. with all appendages), healthy specimens were used for the experiment.

Twelve outdoor tanks of two sizes were set up in April 1993 with crayfish densities of 14 $m^{-2}$, either of just native, signal or narrow-claw crayfish as controls, or as mixed colonies (see Holdich *et al.*, 1993c). In all cases the sex ratio was 3:1 in favour of males - this was determined by the availability of specimens. The tanks were drained and examined every month until September 1993 when the experiments were terminated. Each tank contained an excess of hides and the crayfish were regularly supplied with food. All tanks had running mains water and, on average, the water temperature in the tanks remained 5-6°C below that of static tanks close by.

**Results**

Table 2.8 gives a break-down of the results from both sets of tanks, both individually and combined. All tanks showed a decline in numbers from the start to the end of the experiments. This is shown graphically for each sampling time in Figures 6-8. It can clearly be seen from Figures 6 and 7 that there has been an adverse impact of signals on both native and narrow-clawed crayfish populations. Interestingly, native and narrow-clawed crayfish appeared able to live together without significant impact on each other's numbers, at least for the duration of the experiment (Figure 8). It should be noted in Figure 8 that the survival axis does not go below 40%.

Statistical analysis showed that there was no significant difference between the results obtained in the two sizes of tanks or in each pair of experiments, and thus the results were combined. Table 2.9 shows that there was a significant difference between numbers of crayfish at the start compared with the finish in the tanks containing the signal and narrow-clawed crayfish, and signal and native crayfish, but not with native and narrow-clawed crayfish. When the survival of signal crayfish alone is compared with their survival when they are with native or narrow-clawed crayfish then the probability of the null hypothesis is close to the 0.05 limit. However, when the survival of native and narrow-clawed crayfish alone is compared with when they are with signals, then the results are significant at the $P<0.001$ level. When native and narrow-clawed crayfish alone are compared with when they were together then the result is not significant

**Table 2.8 Results of adult competition experiments to show numbers at the start and end of experiment in mixed and single species tanks**

| **Tank no.** | **1** | **2** | **3** | **4** | **5** | **6** |
|---|---|---|---|---|---|---|
| **Species**[1] | **T/S** | **T** | **T/N** | **S** | **S/N** | **N** |
| Start[2] Expt. 1 | 12/12 | 24 | 12/12 | 24 | 12/12 | 24 |
| Finish[2] Expt. 1 | 0/9 | 16 | 9/4 | 6 | 4/0 | 16 |
| **Tank no.** | **7** | **8** | **9** | **10** | **11** | **12** |
| Start[2] Expt. 2 | 24/24 | 48 | 24/24 | 48 | 24/24 | 48 |
| Finish[2] Expt. 2 | 2/15 | 32 | 18/15 | 24 | 11/1 | 20 |
| **Combined Start** | 36/36 | 72 | 36/36 | 72 | 36/36 | 72 |
| **Combined Finish** | 2/24 | 48 | 27/19 | 30 | 15/1 | 36 |

Notes: [1]N = native, S = signal and T = narrow-clawed crayfish
[2]Experiments started on 27 April 1993 and ended on 22 Sept. 1993

Table 2.9 **Statistical analysis of data in Table 2.8: Chi-squared test**

| Comparison | Expt. 1 | Expt. 2 | Expt. 1+2 |
|---|---|---|---|
| S vs T mixed | *** | *** | *** |
| T vs N mixed | NS | NS | NS |
| S vs N mixed | * | * | * |
| S alone vs S mixed with T | * | NS | * |
| S alone vs S mixed with N | NS | * | NS |
| T alone vs T mixed with S | ** | *** | *** |
| T alone vs T mixed with N | NS | NS | NS |
| N alone vs N mixed with S | ** | ** | *** |
| N alone vs N mixed with T | NS | NS | NS |

Notes: NS: $P>0.05$, *: $P<0.05$, **: $P<0.01$, ***: $P<0.001$
N = native, S = signal and T = narrow-clawed crayfish

**Discussion**

The results indicate that all three species are cannibalistic. No dead bodies were found in the single species tanks and it has been found that crayfish will not eat dead crayfish. The crayfish could not escape and there were no other predators, and yet the numbers declined. All crayfish were free of crayfish plague and no other disease were apparent. The results also clearly show that signal crayfish are predatory on both native and narrow-clawed crayfish. However, it is not clear whether narrow-clawed crayfish are predatory on natives or *vice versa*.

The predatory activities of signal crayfish may well play an important part in the elimination of native crayfish populations when the species become mixed. Those mixed populations in St Catharine's Brook, Dick Brook and Boxmoor Fishery (see Section 2.3) all survived for at least five years, suggesting that the signal crayfish were free of crayfish plague, but the natives now appear to have been eliminated. The only signal population known to live upstream of a native population is in Broadmead Brook (see Section 2.3 and Holdich & Reeve, 1991). The situation here is being carefully monitored to try and "catch" the point at which the populations become mixed, so that the outcome can be followed. Considering the speed at which signals spread, e.g. in the Great Ouse and Gaddesby Brook (see Section 2.3), it is surprising that this has not happened yet.

Interestingly, in Finland, the noble crayfish population of a 4.2-ha lake disappeared in the 1930s and again in the 1960s, probably due to crayfish plague (Westman *et al.*, 1993a). Signal crayfish were released into lake in 1971, and in the same year a small population of noble crayfish were found in the lake. Both species have continued to expand in numbers and have now survived together for 20 years (Westman et al., 1993a, b). It is considered, although there is no experimental evidence, that the noble crayfish, because of its size and fecundity (which is similar to that of the signal crayfish), would have a similar impact on native crayfish in Britain to that inflicted by disease-free signal crayfish. This was the reason it was put on Schedule 9 of the Wildlife & Countryside Act (see Holdich *et al.*, 1993a).

The native and narrow-clawed (Turkish) crayfish appeared to have little effect on each other during the experiment. There is only one known case where the two species occur in the same river catchment (see Section 3.2.1). In that case parts of the R. Stour which previously held native crayfish are now occupied by narrow-clawed crayfish, and native crayfish have not been seen for a number of years. It is not known whether this is due to the presence of the alien species.

### 2.4.2 Juvenile experiments

Many experiments involving juveniles have been carried out during the year, both indoors and outdoors, in 1:1 and mixed-species groups. Although, once again, signal crayfish dominated in most situations, the results so far are not as conclusive as the adult competition experiments. Further analysis is necessary and will be reported on in a Progress Report during 1994.

### 2.4.3 Interspecific mating

#### Introduction

One way in which introduced crayfish species can interfere with the native species is by attempting to mate with it (Holdich, 1988). If the cross-mated female lays infertile eggs then she is effectively taken out of the breeding stock for a year. The authors know of no crayfish hybrids having been reported, but attempted cross mating between signal and native crayfish is known (Frayling, pers. comm.).

An experiment was set up at the start of the breeding season to determine which of the three species (native, signal and narrow-claw) would mate with each other, which successfully laid eggs, and what happens to the eggs.

#### Materials and methods

Males of each species were placed in outdoor tanks with groups of unmated females of the other two species in October 1993 and monitored over the next 18 weeks. Single-species controls were also carried out, as were female:female trials to see if females laid eggs without the presence of males.

#### Results

Out of all the combinations only the native male/signal female did not mate (Table 2.10). By late December 1993, the native female mated by the narrow-clawed male had lost her eggs, one of the native females mated by a signal male had lost her eggs, and one of the narrow-clawed females mated by a male signal had been predated. By February 1994 only female narrow-clawed crayfish mated by male native or male signal crayfish were still carrying healthy eggs.

**Table 2.10 Mating experiments**

| Sp./sex | Sp./sex | Mating? | Initial outcome | February 1994 outcome |
|---|---|---|---|---|
| S♂ | S♀ | Yes - 6 | Eggs | Eggs - 6♀ |
| S♂ | N♀ | Yes - 5 | Eggs | All lost |
| S♂ | T♀ | Yes - 3 | Eggs | Eggs - 2♀ |
| N♂ | N♀ | Yes - 6 | Eggs | Eggs - 6♀ |
| N♂ | S♀ | No | None | - |
| N♂ | T♀ | Yes - 5 | Eggs | Eggs - 2♀ |
| T♂ | T♀ | Yes - 6 | Eggs | Eggs - 6♀ |
| T♂ | N♀ | Yes - 5 | Eggs | All lost |
| T♂ | S♀ | Yes - 1 | Eggs | All lost |
| S♀ | S♀ | - | No eggs | - |
| N♀ | N♀ | - | No eggs | - |
| T♀ | T♀ | - | No eggs | - |

Notes: S=signal, N=native, T=narrow-clawed crayfish. Three male and six female crayfish were employed in each trial

**Discussion**

The results from this experiment are extremely interesting and show that alien crayfish do interfere with native crayfish and each other by cross mating. In the case of mixed native/signal populations this may have contributed to the decline of the natives (see Section 2.3.2). Although most eggs died and were subsequently lost from the successful cross-matings, there were some instances where development appears to have been initiated. The experiments continue to be monitored and will be repeated this autumn.

## 2.5 Environmental impact experiment

**Introduction**

Although alien crayfish in Britain can reach high densities (Reeve, 1991; Section 2.3) it has proved difficult to quantify the impact that they are having on the freshwater environment. However, in North America, *Orconectes rusticus*, which has been introduced into a number of lakes, is known to be responsible for changes in species diversity and macrophyte cover

(Capelli, 1982). The same could happen if *Orconectes virilis* were introduced into some Canadian lakes (Chambers *et al.*, 1990; Hanson *et al.*, 1990). In order to try quantify the impact that *O. virilis* might have on such freshwater ecosystems these workers carried out detailed laboratory experiments using relatively small pools (4.67 $m^2$) stocked with a variety of macrophytes and macroinvertebrates.

In order to see whether this approach could be used with native and signal crayfish, a pilot experiment on the impact of crayfish on macrophyte and macroinvertebrate communities was conducted in 1993.

**Materials and methods**

In May 1993, 16 tanks (380x230x110 mm) were planted with equal quantities of starwort (*Callitriche* sp.) rooted in equal quantities of substrate which was a mixture of silt from a local stream and gravel. The tanks were left undisturbed in an outdoor sheltered site for five weeks, to allow development of plant and invertebrate communities. Juvenile (0+) crayfish were introduced in late June, to give single species populations in each tank except controls. At a density of 20 crayfish per tank (229 $m^{-2}$), four treatments, i) native, ii) signal and iii) narrow-clawed crayfish and iv) a control were replicated. These treatments were repeated at a density of five crayfish per tank (57 $m^{-2}$). The tanks were arranged in a Latin square.

The tanks were then left undisturbed for the rest of the summer. No additional food was provided, the crayfish relying entirely on the plant and invertebrate populations in the tanks. At the end of September, 14 weeks after introduction of the crayfish, the tanks were dismantled and the communities examined.

**Results**

Mortalities of native and narrow-clawed crayfish were high. There were striking differences between the communities in tanks which had signals and those in the controls (Table 2.11). In the control tanks wet mass and diversity of macrophytes were greater, as were numbers and diversity of macroinvertebrates. These observations were most marked when comparing controls with the tanks containing the higher density of signals, but also held to some extent for the comparison between controls and the tanks containing the lower density of signals. It is clear that the signal crayfish had had a substantial influence on the growth and development of the communities. Growth rates of the crayfish themselves were greater in the lower-density populations, presumably because of less competition for food.

**Discussion**

It is thought that the reason for the high mortalities of native and narrow-clawed crayfish was high water temperatures reached during sunny weather. These animals were at development stage 2 when introduced to the tanks (i.e. after the first moult), whereas the signals were at stage 4 (i.e. three moults since hatching), and were therefore likely to have been more vulnerable. Different developmental stages of experimental animals were used to reflect the situation in the wild where signals become independent earlier in the year.

The results provide indications of the potentially dramatic impact of signal crayfish on freshwater communities, and it would clearly be valuable to repeat the experiment in modified form in 1994 (see Section 4.5).

As both signal and narrow-clawed crayfish have a wider range of environmental tolerances than native crayfish (Firkins, 1993; Firkins & Holdich, 1993), it is possible that they will move into areas not currently occupied by crayfish, where they could have a dramatic impact, as has happened with *Orconectes rusticus* in North America (Capelli, 1982).

Chambers *et al.* (1990) found that *Orconectes virilis* significantly affected biomass, density and/or shoot morphology of four macrophytes species in a semi-natural experiment. Hansen *et al.* (1990) also found that this species significantly reduced macroinvertebrates, particularly molluscs, in a similar experiment.

The introduction of alien crayfish into waters which do not possess crayfish could pose serious problems for the macrophyte and macroinvertebrate communities. This could be a problem for somewhere like Scotland, hence the proposal for the whole of this country to be considered for "no-go" status (see Section 2.2). Such an impact may become apparent in the Owston Brook catchment mentioned in Section 2.3.1 and Appendix B. Even when crayfish are or have been present, the introduction of an alien crayfish species could have a dramatic impact, as their population density usually becomes much greater than that of the native species (Holdich, pers. obs.) and consequently they consume more food.

**Table 2.11 Experimental investigation of the impact of juvenile signal crayfish on macrophyte and macroinvertebrate communities**

| crayfish per tank | replicate | surviving crayfish no. | surviving crayfish m[4] | macrophytes m[4] | macrophytes sp[5] | macroinvertebrates Mollusca[1] no. | Mollusca[1] sp[5] | Crustacea[2] no. | Crustacea[2] sp[5] | others[3] no. | others[3] sp[5] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| none | 1 | | | 203 | 4 | 90 | 2 | 11 | 2 | 30 | 3 |
| | 2 | | | 124 | 5 | 20 | 2 | 60 | 1 | 30 | 5 |
| | 3 | | | 228 | 5 | 80 | 2 | * | 1 | * | 1 |
| | 4 | | | 168 | 4 | 30 | 2 | * | 1 | 8 | 1 |
| 5 | 1 | 2 | 1.98 | 160 | 4 | 90 | 2 | 3 | 1 | 10 | 1 |
| | 2 | 4 | 4.64 | 110 | 3 | 20 | 2 | 0 | 0 | 0 | 0 |
| 20 | 1 | 16 | 6.72 | 98 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 17 | 7.41 | 84 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |

Notes: [1]*Limnaea* and Planorbidae (Gastropoda)
[2]*Asellus* (Isopoda) and *Crangonyx* (Amphipoda)
[3]Turbellaria, Oligochaeta, Hirudinea and Insecta
[4]*total wet mass, g* — **data not available*
[5]number of species — Counts of ≥20 individuals are estimates

## 2.6 Publicity

### 2.6.1 Publications

Various aspects of the project have been mentioned in Holdich (1993a, c) and Holdich & Rogers (1992). In addition, Holdich (1993d) reports on the crayfish situation in Wales. Holdich (1992b) attempts to get some uniformity amongst crayfish workers regarding species names and terminology.

Gledhill *et al.* (1993) have produced a new version of the FBA key on the "British Freshwater Crustacea Malacostraca." This contains a useful piece on crayfish which included some input from Nottingham University.

### 2.6.2 Identification leaflet/poster

This has now been completed and is included in Appendix B.

### 2.6.3 Press and television

In November considerable television and local and national press coverage was given to the expanding population of signals in Owston Brook near Melton Mowbray (see Section 2.3.1). Locals had complained about the aggressive nature and burrowing activities of these "monster fish". After a front-page headline in *The Leicester Mercury* the NRA Severn-Trent Region office and Nottingham University were subject to much questioning by the press. The NRA Area Principal Fisheries Officer arranged for a press conference on site which was attended by a number of journalists, radio commentators and Central and BBC Television. Interviews were given by NRA and Nottingham University personnel and broadcast the same day on both channels a number of times. Subsequently the story was picked up by a number of radio stations and newspapers throughout Britain. *The Guardian* did a good piece on the problems of alien crayfish escaping into the wild.

The fact that narrow-clawed crayfish are being harvested from the Serpentine lake in Hyde Park and shipped off to restaurants in Paris created some interest amongst the press (*Daily Mail* and *Evening Standard*).

John Skelton, an ecological photographer from York, arranged for Yorkshire Television to visit a native crayfish site in Yorkshire to highlight the fact that they were an important component of rivers. This was broadcast and also reported in local newspapers. Skelton has also made an interesting video along the same lines and Nottingham University have purchased a copy.

## 2.7 Crayfish farming

### Introduction

It is apparent from press reports that the farming of signal crayfish is still being highlighted a good thing for farmers and others to diversify into. According to an article in *L'Astaciculteur de France* (No. 37, December, 1993) reporting on FAO figures, England produces 15 tonnes of signal crayfish per annum thus making England the largest producer of farmed crayfish in Europe, followed by Sweden with 8 tonnes and France with 5 tonnes. It seems highly unlikely that this is the case. An effort has been made below to put crayfish farming in Britain in perspective. Auchterlonie (1993) and Holdich (1993a, c) have both reviewed the situation in Britain.

### Press

*The Times* of 4 Sept. 1993 reported on an interview with Ken Richards (the original importer and distributer of signal crayfish) in the "Food and Drink" section. The virtues of signal crayfish (including the fact that they may be an aphrodisiac) were outlined. Richards was quoted as saying that some 50-100 tons were being produced from more than 1000 ponds around the country. He makes mention of the fact that he was castigated by ecologists for bringing crayfish plague into the country but he claims he has now been vindicated.

### Article by MAFF

The figures given by Richards differ somewhat from those of Auchterlonie (1993) of the Fish Diseases Laboratory, Weymouth. According to that author, in June 1992 MAFF had 82 freshwater shellfish sites registered, although since then four new sites had registered, two were pending registration, and eight had deregistered. Table 2.12 compares these figures with ones previously made available to us by MAFF. The increase from 69 in 1990 to 82 in 1992 is mainly due to new registrations in the Anglian and Wessex NRA Regions. Of the registered sites only 35 were producing signal crayfish in 1992 with production levels ranging from 2 kg to 2000 kg per annum. Several sites, however, had stock which had not been harvested due to poor market conditions. Total industry production was estimated at 6.5 tonnes. Farmers reported a total of 84 UK customers and 11 export customers. At 1992 prices (£13 $kg^{-1}$) the industry was estimated to be worth £84 000. According to Auchterlonie the likely tonnage produced in 1992 differs somewhat from figures quoted by MAFF, SOAFD and DANI for production in 1990 of 15 tonnes with a value of £100 000.

Auchterlonie comments on the lack of a co-ordinated marketing strategy for the crayfish industry. He states that in some cases, harvesting of stocks has been completely abandoned, leading to stunted, unharvested populations or widespread movement of signal crayfish off site as the carrying capacity of the site is exceeded. He states that in practical terms it would be virtually impossible to provide a 100% escape-proof culture system for signal crayfish.

Auchterlonie points out the probability that with the single European market there will be wider-ranging transport of salmonids. Movement of fish from mixed crayfish and fish sites (some 78% of crayfish "farms" being in this category in Britain) could lead to crayfish plague also being spread with such fish and their transport water. He comments on the role of signal crayfish as vectors of fish pathogens such as IPNV and *Yersinia ruckeri* (the causative organism of ERM).

Auchterlonie says that many crayfish farmers appear ignorant of the laws concerning crayfish. He has doubts that all crayfish "farms" are registered, considering the number of people receiving live crayfish for ongrowing and restocking.

Finally, Auchterlonie suggests that research channelled into, for example, the area of effective containment measures for signal crayfish in farmed conditions (see Section 2.3.4), and diagnosis of crayfish plague carrier status, would be a worthwhile measure towards limiting the ecological costs of the industry.

It is worth noting that ADAS are still advising farmers to diversify into signal crayfish. A report (J. Skelton, pers. comm.) from a meeting between farmers and ADAS in Yorkshire indicates to us that some ADAS personnel are unaware of the problems (Skelton pers. comm.).

**Table 2.12 MAFF-registered fish farm sites holding crayfish**

| NRA Region | 1990 | 1992 |
|---|---|---|
| Anglian | 10 | 14 |
| Northumbrian | -- | -- |
| North West | 1 | 1 |
| Severn Trent | 6 | 6 |
| Southern | 13 | 14 |
| South West | 1 | 2 |
| Thames | 13 | 13 |
| Wessex | 22 | 28 |
| Yorkshire | 1 | 1 |
| Welsh | 2 | 3 |
| Total | 69 | 82 |

**Results of questionnaire sent out to crayfish farmers**

The information from MAFF reported above is only summarised data, available to the general public. The individual farm data, which over the past two years have improved dramatically are restricted to use for disease control only. Despite requests, Nottingham University has not been given access to these data and has built up its own records by undertaking a survey of crayfish farms. The information available indicated that there have been approximately 300 implants of signal crayfish between 1976 and 1990 and that currently there are 92 sites housing breeding populations, leading to the conclusion that a large number of implants have been unsuccessful (Holdich & Reeve, 1991).

In order to obtain up-to-date information a questionnaire was sent in 1993 to 49 of the most active sites of crayfish production. This yielded an excellent response of 32 replies, and this has been improved by follow-up letters and telephone interviews making 36 (73%) replies in total.

Of the 36 respondents, 23 (64%) declared that their farm was not profitable. Of the 13 profitable sites, four proprietors did not sell crayfish for the table market as their only product. They sold either juvenile crayfish, equipment or advice in addition. Of the remaining nine enterprises producing solely for the table market, four expressed difficulties and major reductions in sales and profits since the demise of the cooperative marketing organisation, the British Crayfish Marketing Association (BCMA) in 1990.

**Comment**

The current picture of the crayfish farming industry in Britain today is one of mainly small, disjointed enterprises which in most cases have lost their novelty value and have been unable to maintain the high prices achieved in the mid-1980s for marketing their product (prices are known to have fallen and a more usual price is now £7.50 $kg^{-1}$). Many signal crayfish populations have been abandoned. Eventually escapes reach local water courses and thus constitute an ecological threat.

As populations of signal crayfish have consolidated their positions in the wild in rivers and lakes, a new resource has presented itself for exploitation. Added to these wild signal populations, escapes of imported narrow-clawed crayfish, which have established large populations in several lakes around London (see Section 2.3.2), means trapping from the wild is becoming an increasing percentage of the national production. Netsmen exploiting this resource are now estimated to account for 15% of the production in Britain.

As well as being vectors of crayfish plague (North American crayfish) and possibly of IPNV (noble crayfish), it is worth noting that researchers in Australia have isolated a new virus from crayfish. Previously this had only been found in protozoans which cause stomach upsets in humans. Although it does not appear to cause problems in the wild or on large farms, there have been heavy mortalities among infected crayfish kept in laboratory containers (*Fish Farming International*, Sept. 1993, p. 22).

## 3. CONCLUSIONS FROM FIRST AND SECOND YEARS

- Crayfish plague outbreaks are continuing to occur in a random manner. However, mortalities of native crayfish appear to be relatively localised.

- The predictable consolidation and spread of signal crayfish populations in the south of England presents an increasing reservoir for the disease, thus presenting an increasing threat to native crayfish populations.

- It is clear that the situation regarding the spread of alien crayfish in the wild is getting worse mainly due to escapes from failed aquaculture ventures. Relatively simple measures, e.g. a 0.3-m lipped barrier, can be implemented to stop escapes in most circumstances as long as there is no outflow of water from the crayfish farm.

- The spread of signal crayfish in particular is cause for concern as very large populations are now present in some rivers and streams. They burrow extensively into banks and consume large amounts of animal and vegetable matter. Laboratory experiments indicate that their impact on the environment is likely to be greater than that of native crayfish. However, this is proving difficult to verify in the field as there are few situations where comparisons between the species can be made.

- Narrow-clawed crayfish are still largely confined to the environs of London. In Tykes Water, Aldenham Reservoir and the Serpentine lake they have built up huge populations which, in the case of the latter two sites, are being harvested. They have also colonised a river in Suffolk, but it remains to be seen whether they undergo the sort of population growth that has occurred in lakes.

- On the positive side, however, new records for native crayfish are still being regularly received. Public awareness of the threats to the native crayfish has increased. It is intended to build on this awareness with the publication of an explanatory leaflet/poster. The conservation measures being recommended by the JNCC, if implemented, should enable the native crayfish to survive in many areas.

- Signal crayfish are still perceived as having aquaculture potential, and given suitable water quality, substrate and climate there appears to be no reason why economically viable units should not proliferate, particularly in the south of England. Despite an increasing awareness of the problems arising from the introduction of alien species, entrepreneurs and farmers are still being encouraged to embark upon crayfish culture as a form of agricultural diversification. However, currently the industry remains small according to production figures produced by MAFF and our own studies.

- At Dinesens' crayfish farm, it has been shown that purpose-built ponds can yield 400 kg $ha^{-1}$ whereas prior to this a sustainable yield of 200 kg $ha^{-1}$ from lake ranching in gravel pits was considered to be the most intensive form of commercial production. It is clear that either much greater land use or intensification is required if Britain is to achieve a viable commercial astaciculture industry. Supply of a high quality aquaculture product by farming could be undermined by netsmen harvesting a variable quality wild catch from feral populations of signal and narrow-clawed crayfish.

- It is clear from laboratory experiments that the presence of plague-free signal crayfish is detrimental to both native and narrow-clawed crayfish, although the latter two species seem able to cohabit. The mixed native/signal populations previously known from Dick Brook (Worcs), St Catharine's Brook (Bristol Avon) and Boxmoor Fishery (Hemel Hempstead) all seem to have become monospecific in the signal's favour.

- Control of alien crayfish in the wild is going to be expensive in terms of time and money. More work needs to be done to find the best means of reducing or eliminating populations.

# 4. PROGRAMME TO BE FOLLOWED IN 1994

## 4.1 Distribution

### 4.1.1 Database

New records will be put into a form which can be processed for the ITE national database. All those people who responded to the questionnaire (see Holdich *et al.*, 1992c) will be recontacted to see if they have additional information. They will be supplied with a copy of the poster/leaflet (see Section 2.6.2).

## 4.2 "No-go" areas

If the Government Ministers' response to JNCC's conservation strategy is favourable then consideration will be given to the question of how the policy could be implemented.

## 4.3 Field work

### 4.3.1 River Wreake catchment (Leics)

It is hoped to carry out a detailed survey of the signal crayfish in this catchment if additional funds are forthcoming (see Appendix C). English Nature have been approached about possible funding. There is a need for two persons to spend some time on site surveying the area this summer. The extent of the problem needs working out as does the feasibility of controlling the spread. An ideal opportunity presents itself to monitor the impact that the signal crayfish are having on small brooks.

### 4.3.2 River Stour (Suffolk)

Further trapping will be carried out to assess the extent of the invasion by narrow-clawed crayfish. The sources of the population and the means by which it is entering the river will be examined.

### 4.3.3 Boxmoor Fishery (Herts)

A AFRC studentship applied for to study this population in detail but was unsuccessful. It is planned to present a poster about this study at the Adelaide symposium (see Section 4.6.1).

### 4.3.3 Tykes Water

Further monitoring of the situation will be undertaken. However, now that the anglers have purchased their own fyke nets, the expense will be minimal.

### 4.3.4 Serpentine

The trapping of the narrow-clawed crayfish population from the Serpentine will continue to be monitored.

### 4.3.5 Lincolnshire

Further visits will be made to assist NRA Anglian Region in their study of the signal crayfish populations in the R. Bain and R. Ancholme with a view to containment or elimination.

### 4.3.6 Dinensens' crayfish farm

A large body of information has been obtained and is currently being analysed. It may not be necessary to make more than one more trip to tie things up. However, there is a wealth of work that could be done on the populations. A AFRC studentship was applied for to work on this population and that at Boxmoor (see Section 4.3.3) but was unsuccessful.

### 4.3.7 *Procambarus clarkii*

In the summer an attempt will be made to assess the status of the crayfish populations in the ponds on Hampstead Heath. The main aim of this study will be to see if red swamp crayfish are still present and, if so, whether a number of cohorts are present which may indicate whether they are breeding or not.

## 4.4 Competition experiments

It is not planned to repeat the adult competition experiments, mainly because of the number of native crayfish which would be needed. However, experiments with juveniles and between adults and juveniles will be carried out in early summer.

Interspecific mating experiments will be repeated and extended to include mixed species groups of females.

## 4.5 Environmental impact

New environmental impact experiments involving juveniles of all three species will be set up in a more controlled manner in 1994. Steps will be taken to control variations in biomass and mortality between the three species, and to ensure greater uniformity of macroinvertebrate communities at the start of the experiment. In addition, it is hoped to assess the impact of signals *via* a field study (see Appendix C).

## 4.6 Publicity

The poster/leaflet will be widely distributed by both the NRA and Nottingham University.

### 4.6.1 Symposium

David Holdich and David Rogers are planning to attend the 10th International Association of Astacology symposium in Adelaide in April, 1994. They will both be presenting papers and posters (approved by the Project Leader) relating to work done on the contract. This is a good forum to discuss matters such as management of alien crayfish, as many other countries have similar problems. The papers from the proceedings are published and widely disseminated (e.g. Holdich & Warner, 1993).

## 4.7 Containment of alien crayfish

It is planned to devise a series of laboratory experiments on methods to of prevent crayfish escaping through the inlet and outlet pipes of crayfish farms.

## 4.8 Management of wild alien crayfish populations

The studies on Boxmoor, north Lincolnshire, the R. Stour and Owston Brook (see Section 2.3) are aimed at gaining additional information about this problem. In addition, information is being gathered on how other countries are tackling the problem of alien crayfish introductions.

## 4.9 Final Report

From December to the end of January 1995 most of the time will be taken up preparing the Final Report.

## 5. ACKNOWLEDGEMENTS

The authors of this report would like to thank the many people who have provided crayfish records. Special thanks are due to Martin Frayling (NRA South Western Region), David Ford (NRA Severn Trent Region) and Jerry Domaniewski (Reading University) for their help with work on Broadmead Brook, Owston Brook and Boxmoor Fishery respectively; to Muzaffer Harlioglu and Tracey Marsland for their help with experiments at Nottingham University; to Ruishang Guan and Roy Wiles (University of Buckingham) for access to their data for the Great Ouse; and to Ian Firkins for his help with records and field work.

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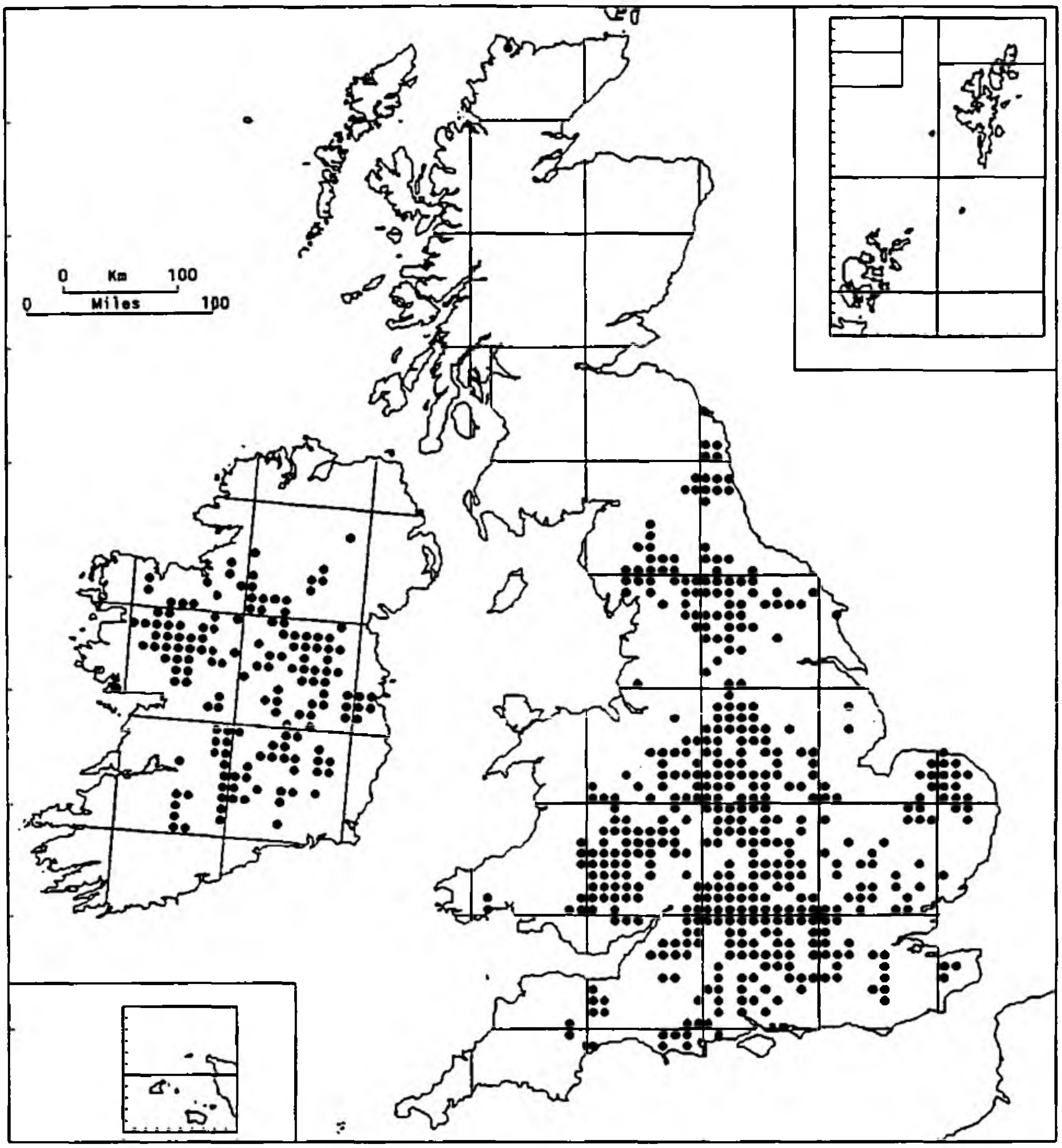
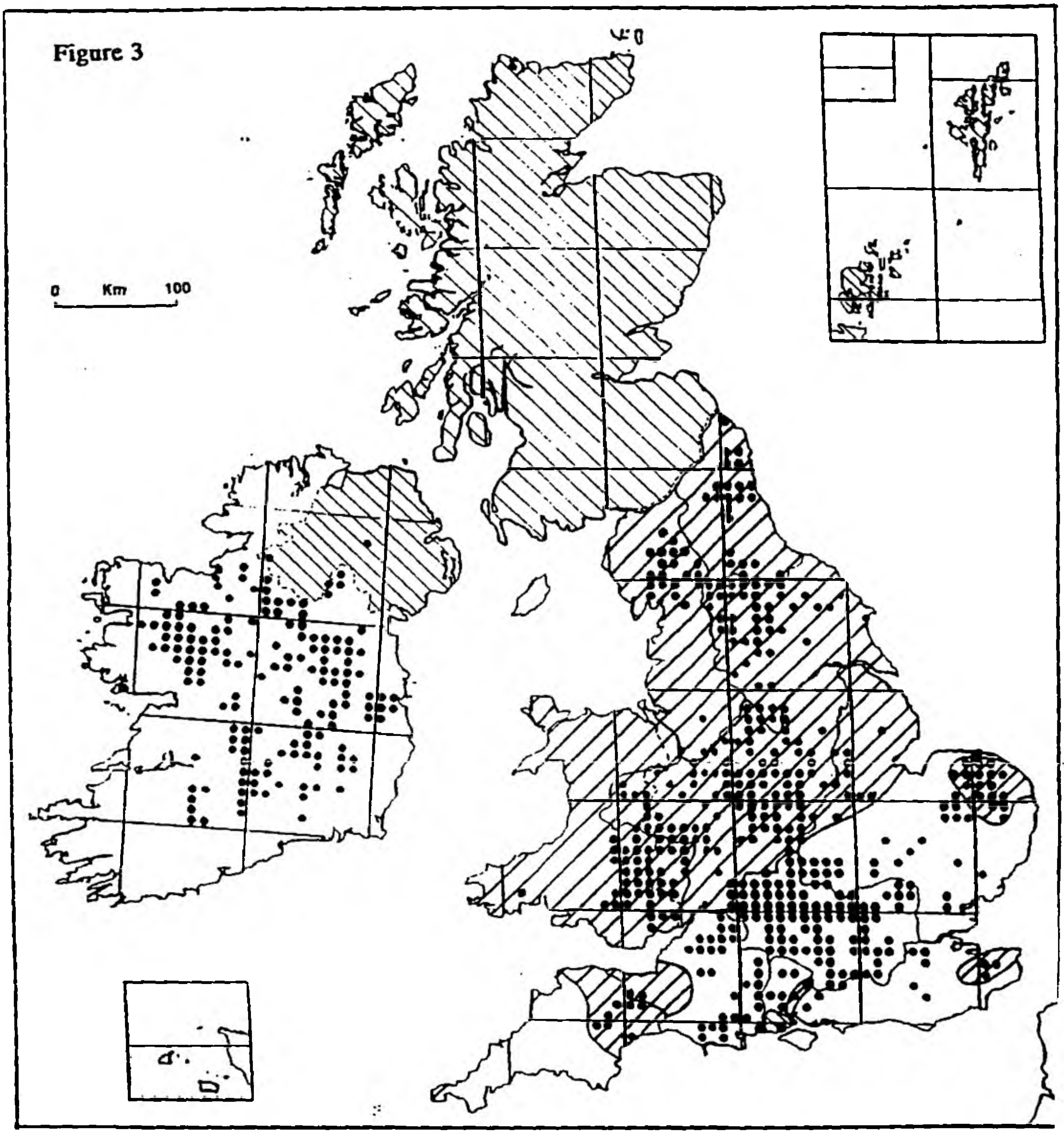



Figure 1 Distribution (1970-1993 inc.) of the native, white-clawed crayfish in the British Isles on a ten-kilometre square basis.


Figure 2 River catchments in England and Wales in which mortalities of the native crayfish, confirmed or suspected to have been caused by crayfish plague, have occurred from 1981 to 1993 inclusive.

Map of the British Isles showing the distribution of *Austropotamobius pallipes* (all records 1970-1993) on a 10-km square basis and the proposed "no-go" areas for crayfish farming in England, Wales, Scotland and Northern Ireland. Thick diagonal are areas agreed in principle by the NRA and conservation agencies, narrow diagonal lines are extra proposals by conservation agencies. Also shown are the NRA regional boundaries (continuous lines) and the country boundaries (dashed lines). The Republic of Ireland, the Channel Islands and the Isle of Man are not covered by these proposals.




<u>Definitions of "no-go" area boundaries.</u> (The conservation agencies would also like to include the whole of Scotland and Northern Ireland).

The boundary from the Bristol Channel to the Wash initially follows the boundary between the Wessex and Severn-Trent NRA Regions, then that between the Severn-Trent and the Thames. It then runs northwards along the border between the Anglian/Severn-Trent Regions until it reaches the point where the catchments of the R. Nene and R. Welland divide, and thence to the Wash including the R. Welland but not the R. Nene.

The "no-go" area in Norfolk includes the catchments of the R. Bure, R. Wensum and all their tributaries, although it does not include the R. Waveney.

The "no-go" areas in the Southern NRA Region are the catchments of the Great Stour and its tributaries, and the R. Itchen and its tributaries. The conservation agencies would also like to include the New Forest. This would be defined by the Wessex/Southern NRA boundary to the west and excludes the R. Blackwater to the north.

The "no-go" area associated with the South-West and Wessex NRA regional boundary is defined to the west by all rivers to the east of the R. Taw catchment. Following this catchment division southwards, the R. Exe and its tributaries the R. Yeo and R. Creedy are included but rivers to the east of these catchments are excluded. The eastern boundary starts at the south of the South-West/Wessex NRA boundary and then runs northwards to include the catchments of the R. Parrett, R. Brue and R. Axe ending at Weston-super-Mare, and thus includes the Somerset levels.

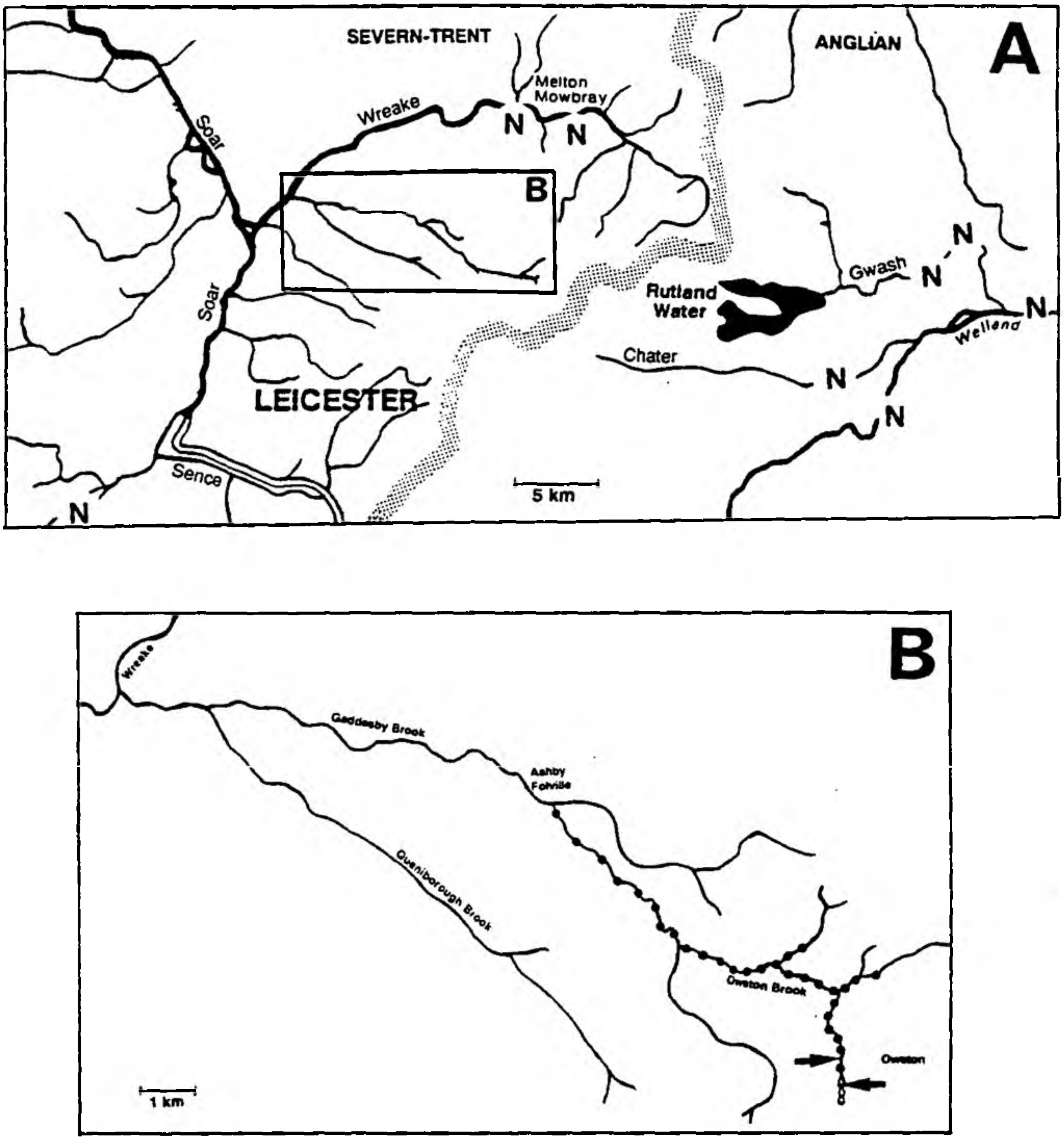



Figure 4 Maps showing location of Owston Brook and spread of signal crayfish in catchment

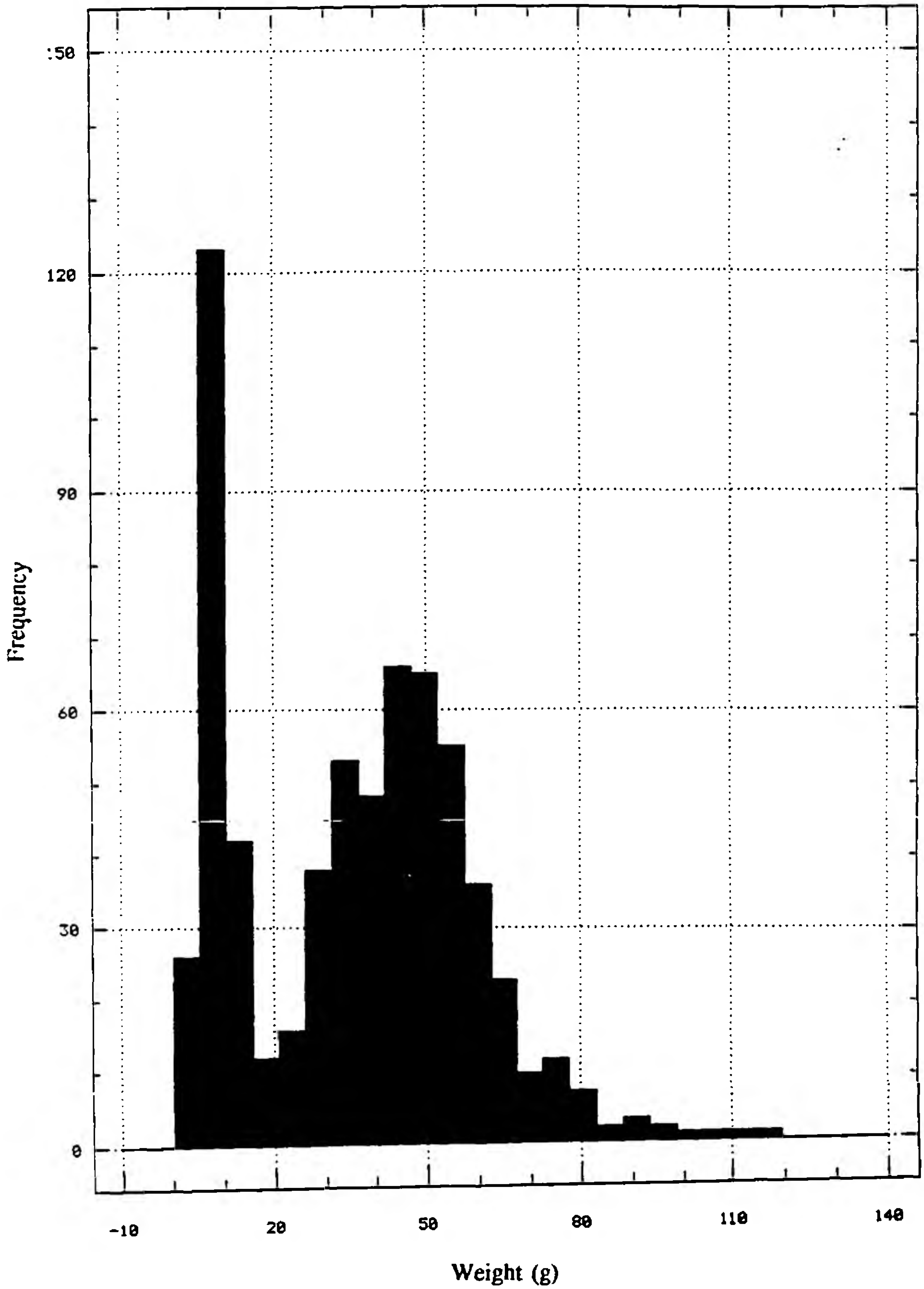



Figure 5 Weight/frequency histogram for signal crayfish in Pond 1 at Dinesens' crayfish farm.

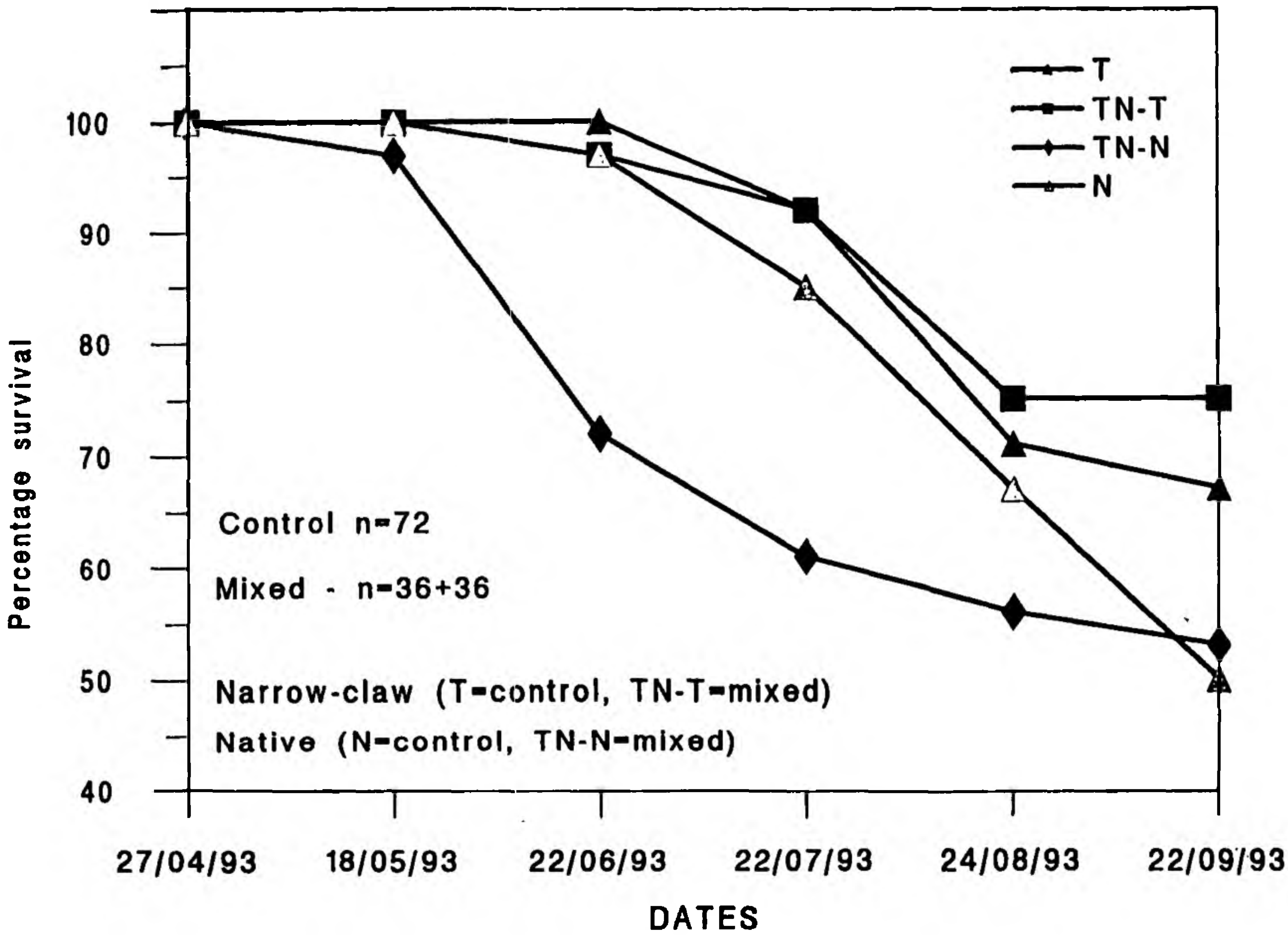



Figure 6 Adult competition experiments - signal *versus* native crayfish.

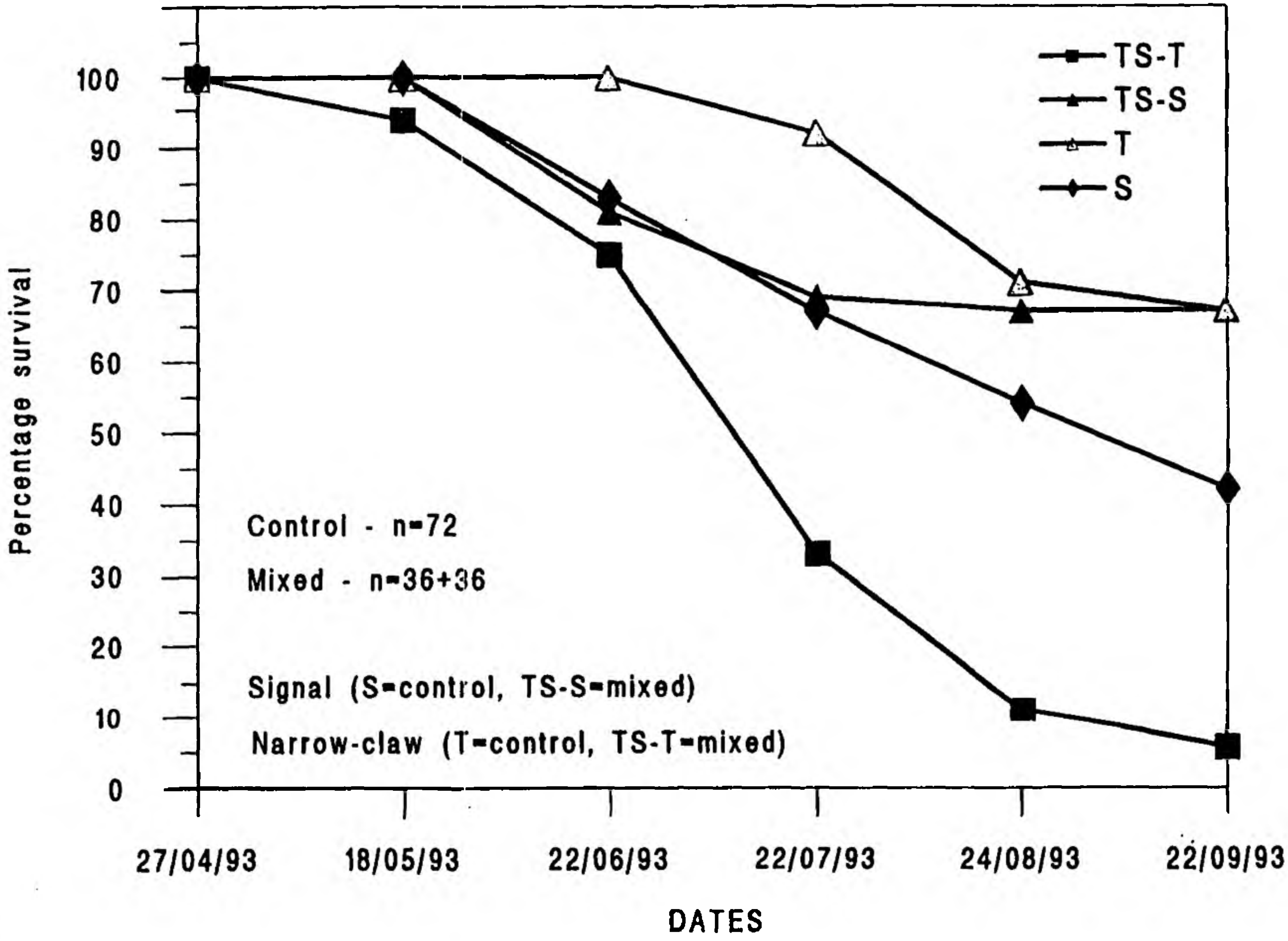



**Figure 7** **Adult competition experiments - signal *versus* narrow-clawed crayfish.**

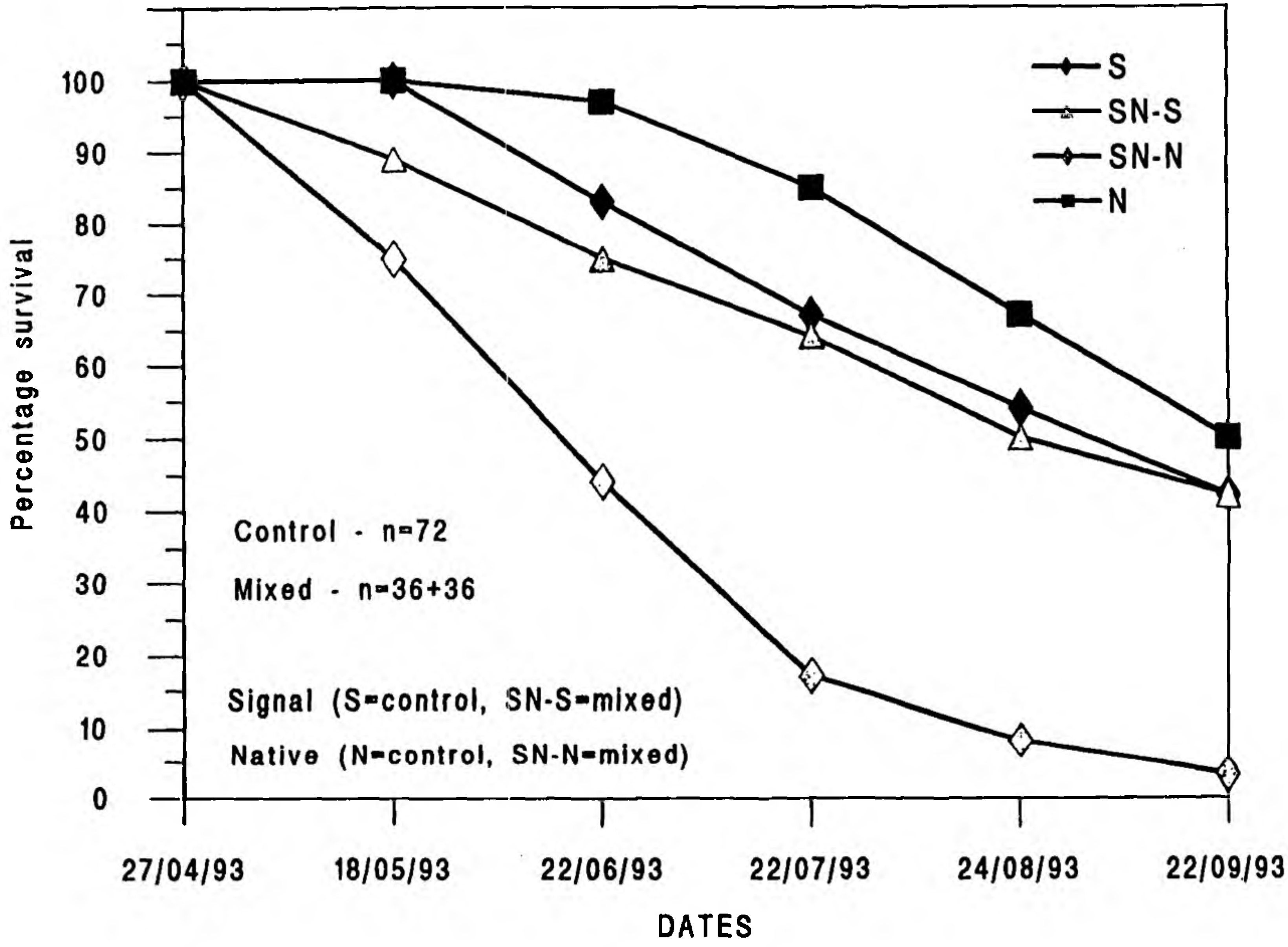



**Figure 8** Adult competition experiments - narrow-clawed *versus* native crayfish.

## APPENDIX A - FINANCES

| Period 01/01/93-31/12/93 | £ |
|---|---|
| Staff | 1 181 |
| Travel/subsistence | 3 056 |
| Tykes Water | 4 113 |
| Consumables | 577 |
| Sub-contract | 17 022 |
| Reports | 39 |
| Others (overheads/professional indemnity insurance) | 16 424 |
| Total | 42 412 |

Estimate of total costs (at current prices)

| | |
|---|---|
| Staff | 3 501 |
| Travel/subsistence | 9 506 |
| Tykes Water | 4 113 |
| Consumables | 2 582 |
| Sub-contract | 50 738 |
| Reports | 800 |
| Others (overheads/professional indemnity insurance) | 49 057 |
| **Total** | **£120 181** |

APPENDIX B - POSTER/LEAFLET

## APPENDIX C - FURTHER RESEARCH

### 1. Restocking

A number of requests have been received about restocking native crayfish into waters previously affected by crayfish plague. MAFF have been consulted over this issue and they consider that while there are still random outbreaks of crayfish it would be premature to undertake such an exercise. However, three reintroductions have been made in the Bristol Avon catchment and these have survived and increased in population density over the last six years (Frayling, pers. comm.). Areas where any introductions were to be considered would have to be studied in detail to assess their suitability. We consider that reintroductions into a small number of suitable trial waters would be worth investigating.

### 2. Management of alien crayfish populations

The following project could be undertaken if more funds were made available. English Nature have been approached to see if they would fund the project outlined below.

#### 2.1 Introduction

The major problem in the future is going to be the continued spread of signal and narrow-clawed crayfish in the wild. How this problem can best be tackled will be something that will be dealt with in the Final Report. So far management has been attempted with only narrow-clawed populations (e.g. Tykes Water, see Section 2.3.2) in lacustrine environments. A similar exercise needs to be repeated in a riverine environment to assess its feasibility. Such a waterbody is available close to Nottingham, i.e. Gaddesby Brook (see Section 2.3.1) and would make an ideal study site if extra money could be found to fund the personnel and facilities needed. This site is also in the public eye and it has been stated by the NRA that something will be done about it.

#### 2.2 Objectives

- To survey the distribution of signal crayfish in the Owston-Gaddesby Brook catchment.
- To determine what the crayfish are eating and the impact they may be having on the associated biota.
- To assess the extent to which the crayfish are burrowing into banks.
- To calculate the density of the crayfish at selected sites.
- To assess the impact of sustained trapping on population numbers.

- To explore methods by which the spread of the crayfish can be managed, including their removal from the site during the course of the project.

- To attempt to assess whether or not the signal crayfish are carrying crayfish plague.

## 2.3 Methods

- The personnel involved will be provided with detailed maps. They will be shown over the area by an NRA Fisheries Officer of Severn-Trent Region, Lower Trent Area and personnel from Nottingham University. The whole of the catchment will be trapped and hand-searched over the three-month period so that the distribution of the signal crayfish is mapped.

- Signal crayfish will be returned to Nottingham and frozen. When time is available the guts will be removed and an analysis made of their contents. This will be coupled with detailed surveys of the macroinvertebrates, fish and plants in brooks with crayfish and without crayfish.

- During routine survey work the extent of burrowing will be determined by direct examination, photography and measurement.

- Traps will be set in selected areas of the brooks at a density of one per three metres. Captured crayfish will be sexed, weighed and measured (to give some idea of the population structure). They will then be marked by pleural clipping and returned. The traps will then be reset and the exercise repeated twice in order to assess the size of the populations by mark and recapture. For comparative purposes, estimation of numbers will be also be done by the removal method.

- Sustained trapping using Swedish "Trappies", perch traps and fyke nets will be carried out in the original implant pools to see whether numbers can be significantly reduced. The traps will be emptied on a daily basis for three days and then the exercise repeated at weekly intervals. Coupled with the mark and recapture exercise mentioned above it should be possible to determine what proportion of the population could be removed over a given time period.

- The experience gained in this exercise will provide information which should enable a management plan to be formulated. This plan will involve the co-operation of local land owners, particularly those owning the original implants pools. The exercise will tell us the extent of the problem and whether it is feasible to remove a large part of the population by trapping. Obviously the effectiveness of any removal exercise will have to be monitored in subsequent years, but this should be a relatively straightforward exercise involving trapping in selected areas over a short period of time.

- Signal crayfish will be returned to Nottingham University and examined for signs of melanisation (a possible sign of the reaction of the cuticle to invasion by the crayfish plague fungus). Native crayfish will be collected (under licence from English Nature) and kept in separate cages with signal crayfish. If the signal crayfish show signs of melanisation then some will be sent to the MAFF Fish Diseases Laboratory at Weymouth, as will any natives exhibiting signs associated with crayfish plague.

## 2.4 Outcome

If this detailed study is undertaken then it would be the first in the country in which an attempt has been made to assess the impact of signal crayfish on the environment with a view to managing the population(s). As many catchments are facing this problem then the information gained will be of national use.

## APPENDIX D - GLOSSARY

**Common and scientific names of crayfish in British waters:**

| | |
|---|---|
| *Astacus astacus* (L.) | - the noble crayfish |
| *Astacus leptodactylus* Eschscholtz | - the narrow-clawed (Turkish) crayfish |
| *Austropotamobius pallipes* (Lereboullet) | - the white-clawed (native) crayfish |
| *Pacifastacus leniusculus* (Dana) | - the signal crayfish |
| *Procambarus clarkii* (Girard) | - the red swamp crayfish |

**Other terms:**

| | |
|---|---|
| "No-go" area | - an area where future ventures into farming crayfish would not be allowed |
| Astaciculture | - the culture of freshwater crayfish |

**Abbreviations:**

| | |
|---|---|
| ADAS | - Agricultural Development Advisory Service |
| AFRC | - Agricultural and Food Research Council |
| CCW | - Countryside Council for Wales |
| CL | - Carapace length |
| CPUE | - Catch per unit effort |
| DANI | - Dept. of Agriculture for Northern Ireland |
| EN | - English Nature |
| ITE | - Institute of Terrestrial Ecology |
| JNCC | - Joint Nature Conservation Committee |
| MAFF | - Ministry of Agriculture, Fisheries & Food |
| NRA | - National Rivers Authority |
| NWC | - National Water Council |
| SAC | - Special area of conservation |
| SNH | - Scottish Natural Heritage |
| SOAFD | - Scottish Office, Agriculture & Fisheries Department |

# IDENTIFYING FRESHWATER CRAYFISH IN BRITAIN AND IRELAND

## White-clawed (native) *(Austropotamobius pallipes)*

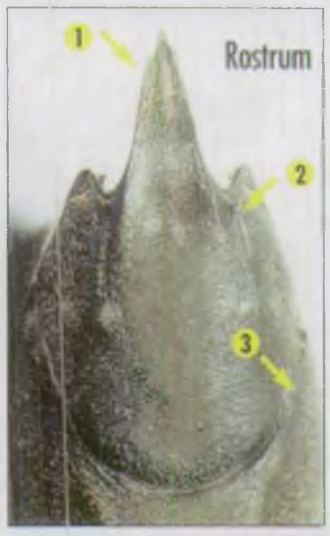
**Size** Seldom greater than 10 cm in body length.

**Rostrum** Sides smooth, converging towards base of small triangular apex ( ↘ 1). Dorsal surface covered in fine mat of hairs. Median ridge discrete.

**Body** Smooth, but carapace with pitted appearance. Pale to dark brown or olive in colour. Single pair of post-orbital ridges with a spine ( ↙ 2). Prominent spines on shoulders of carapace, just behind cervical groove ( ↘ 3). These are present in juveniles as small projections.

**Claws** Top side rough. Underside dirty-white colour in adults, although in juveniles may be pink. More robust in males than females.

**Habits/habitat** Fairly docile. Occupies streams, rivers, lakes, reservoirs, water-filled quarries. Distribution - see Figure 1.


Underside of claw

Male white-clawed crayfish

## Signal *(Pacifastacus leniusculus)*

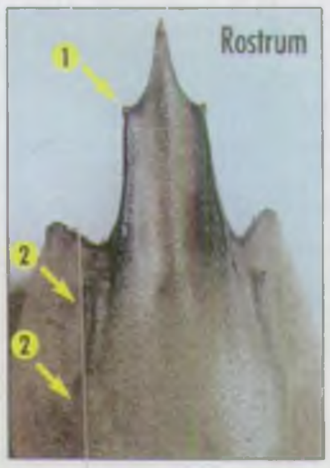
**Size** May reach 15 cm in body length. Heavier than other species due to massive claws.

**Rostrum** Sides smooth and more or less parallel. Median ridge smooth. Apex very pointed and prominent, sides sloping down to prominent shoulders ( ↘ 1) some way from tip.

**Body** Smooth, generally bluish-brown or reddish-brown, may be almost black in colour in some habitats. Two pairs of post-orbital ridges, first with spine ( ↘ 2), although the second ridge may be insignificant.

**Claws** Large, robust and smooth all over; red underneath. White to turqoise patch at joint of moveable and fixed finger ( → 3) gives the signal crayfish its common name.

**Habits/habitat** An aggressive, invasive North American species. Will burrow extensively into suitable substrates. Very good at climbing and escaping. Lives in same habitats as native species. Distribution widespread, particularly in south.




Underside of claw

Male signal crayfish


## Narrow-clawed (Turkish) *(Astacus leptodactylus)*

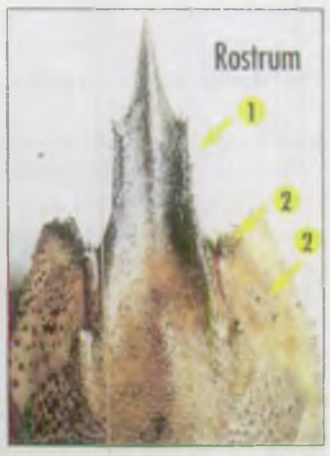
**Size** Males often reaching 15 cm but may get larger.

**Rostrum** Basal part with toothed margins ( ↙ 1). Apex very pointed and prominent.

**Body** Pale yellow to greenish in colour. Sides of carapace rough. Two pairs of post-orbital ridges, both with spines ( ↙ 2). Prominent tubercle on shoulder of carapace ( ↘ ↙ 3).

**Claws** Long and narrow. Longer than body in males. Rough on upper surface. Biting edges almost straight.

**Habits/habitat** Fairly docile, especially males with large claws. Favours relatively still water as in lakes and canals.


Underside of claw

Male narrow-clawed crayfish

## Red swamp *(Procambarus clarkii)*

**Size** May reach 15 cm in length.

**Rostrum** Similar to that of native crayfish but with edges below apex thickened and turning inwards ( ↙ 1).

**Body** Generally red to reddish-brown all over. Carapace rough. Branchio-cardiac grooves abutting in mid-line ( ↑ 2) (other species have space between).

**Claws** Red on both surfaces, covered in tubercles. Large spine on inner margin of carpus ( ↙ 3).

**Habits/habitat** Aggressive. Wide tolerance of environmental conditions. Burrows. Prefers relatively still waters. Has been found in the wild in Britain, but not known if breeding. On sale in aquarist shops as "Red lobsters."

Upperside of claws


Underside of claw

Male red swamp crayfish


## Other species

The only other foreign species of crayfish recorded from British waters is the noble crayfish, *Astacus astacus*, introduced from mainland Europe. Currently this is restricted to a few enclosed ponds.

It is similar to the signal crayfish although less aggressive. There is no white patch on the upperside of the claw and the median ridge of the rostrum is strongly toothed.

# A GUIDE TO IDENTIFYING FRESHWATER CRAYFISH IN BRITAIN AND IRELAND

NRA

*National Rivers Authority*

## Crayfish plague

Crayfish plague is a virulent disease caused by the fungus, *Aphanomyces astaci* Schikora. North American crayfish can carry the fungus but, unless put under stress, seem to suffer no ill effects from it. However, native European crayfish are highly susceptible to the disease. It is thought that crayfish plague was introduced into Italy in the early 1860s and from there it spread rapidly throughout much of Europe, devastating native crayfish populations, particularly those of *Astacus astacus*. One of the reasons *Pacifastacus leniusculus* has been introduced into Europe is to develop stocks of crayfish immune to crayfish plague but with similar characteristics to the noble crayfish. However, as the signal crayfish can act as a vector of the disease this has assisted its spread.

There is no clear evidence that native British crayfish populations had been affected by crayfish plague until very recently. Outbreaks started in the early 1980s and have continued ever since. Many populations of *Austropotamobius pallipes* have been wiped out, particularly in southern England. The disease can be spread by signal crayfish but, in addition, spores of the fungus can be transmitted in water, on damp equipment and mud, and attached to fish. A serious outbreak in central Ireland in the mid-1980s is thought to have been due to visiting anglers using contaminated equipment.

Crayfish are the only host for the crayfish plague fungus, so if all the crayfish have been eliminated, then it should be possible to restock previously affected waters with native crayfish. However, if signal crayfish are in the vicinity then further disease outbreaks may occur.

It is particularly important to realise how virulent crayfish plague is. Equipment, waders etc. used in waters where there are signal crayfish, or where a native crayfish mortality has occurred, should be left to dry out thoroughly or, better still, should be treated with malachite green or an iodophore-based disinfectant. This procedure should always be followed before sampling is carried out in waters containing native crayfish.

## National database

In order to monitor the distribution of native and non- native crayfish a computerised database of records, which is continually updated, has been set up. Accurate information is needed for the database and can be sent to David Holdich or David Rogers, Dept. of Life Science, The University of Nottingham, Nottingham NG7 2RD.

## Legislation and Protection

**Native species** - *Austropotamobius pallipes* is listed on Schedule 5 of the Wildlife & Countryside Act, 1981, giving it protection against "taking and sale" in Britain. It is also included in the IUCN Red Data List and in Appendix III of the Bern Convention and Annexes II and V of the European Habitats and Species Directive. Designation of protected areas is required for species on Annex II.

**Non-native species** - the signal, narrow-clawed (Turkish) and noble crayfish are listed on Schedule 9 of the Wildlife & Countryside Act, which effectively classifies them as pests in Britain. If the red swamp crayfish is found to be breeding in the wild, then it too is likely to be added to the list. Animals listed under Schedule 9 cannot be released into the wild without a licence even though they are considered to be ordinarily resident.

N.B. There is different legislation covering species protection in both Northern Ireland and the Republic of Ireland.

## The NRA and Crayfish Conservation

The NRA has commissioned Nottingham University to undertake a 3 year R&D project to assess the impact of non-native crayfish on freshwater ecosystems and to formulate a strategy for the conservation of the native species. This leaflet is an important part of the research in that it allows biologists and others sampling rivers to more accurately identify crayfish and thereby provide sound information on species distribution.

## Further reading


Alderman, D.J. & Wickins, J.F. (1990). Crayfish culture. MAFF Laboratory Leaflet N. 62, 16 pp. Lowestoft.

Holdich, D.M. (1991). The native crayfish and threats to its existence. *British Wildlife* 2(3): 141-151.

Holdich, D.M. & Reeve, I.D. (1991). Distribution of freshwater crayfish in the British Isles, with particular reference to crayfish plague, alien introductions and water quality. *Aquatic Conservation* 1: 139-158.


## The native crayfish

The British Isles has a single species of native freshwater crayfish - *Austropotamobius pallipes* (Lereboullet), the white-clawed crayfish. Whether this is a glacial relict or has been introduced by man from mainland Europe since the last ice-age is not known.

*Austropotamobius pallipes* has a wide distribution in the British Isles but tends to be confined to areas with relatively hard, alkaline water. It is absent from western Wales, western England and parts of Ireland (Figure 1). It is also naturally absent from Scotland although there are areas with suitable water - indeed one artificially introduced population has survived since the 1940s in the north-west.

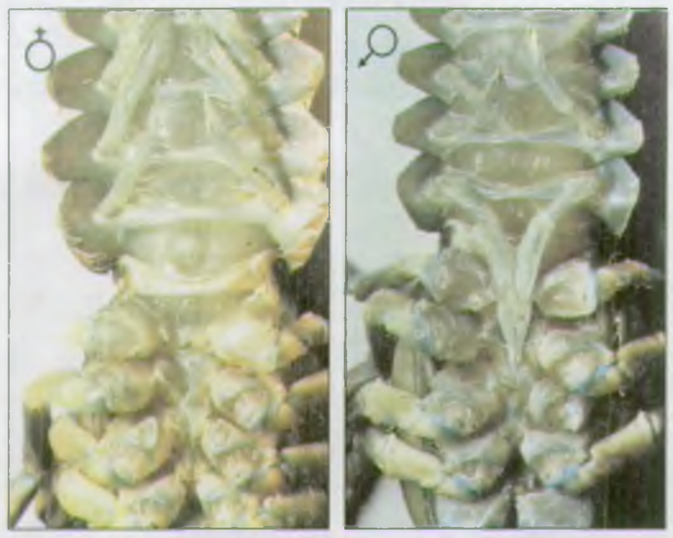
The native crayfish occupies a range of habitats, including streams, rivers, lakes, reservoirs and water-filled quarries. It prefers streams and rivers without too much sediment and is sensitive to biocides and other pollutants, particularly those lowering the oxygen concentration of the water. Shelter, e.g. rocks/stones, macrophytes and tree roots, or a bank into which it can burrow, are important for its survival. It is omnivorous, feeding on a wide variety of vegetable and animal matter. It is eaten by certain fish, e.g. perch, trout, chub, pike and eel, as well as birds, rats, mink and otters. In some areas such as the River Wye in Wales, it forms an important dietary component of the otter. The young also fall victim to carnivorous insect larvae and nymphs (e.g. beetles and dragonflies).

Native crayfish mate in October/November and the female then lays her eggs, which become attached in a cluster to the underside of her abdomen (tail). She overwinters with her brood and in the spring the eggs hatch into relatively immobile, miniature crayfish without a tailfan, which cling to the mother. They then moult to form a second stage, with a rounded, hairy tailfan, and become more active, eventually leaving the mother in May/June. At the next moult they develop a typical crayfish form with an outspread tailfan. During their first year such juveniles may undergo seven or more moults, but by the time they are mature, after 3-4 years, they may moult only once a year.

Male crayfish species tend to have larger claws than females and they are more territorial, particularly in the breeding season. Females develop a broader abdomen to accommodate the brood. Males can be distinguished from females by the appendages on the underside of the abdomen (Figure 2).


Figure 1 - Native crayfish records for the period 1970-93 on a 10km square basis.

Figure 2 - Underside of abdomen to show difference between sexes.




## Introduced species

Other crayfish species have been artificially introduced into the British Isles in the past although no self- sustaining populations appeared until the 1970s. In that decade and subsequently, large quantities of the narrow- clawed (Turkish) crayfish, *Astacus leptodactylus* Eschscholtz were introduced from mainland Europe for the restaurant trade. Some escaped from fish markets and others were deliberately introduced into the wild. Rapidly expanding populations are now known in and around London, particularly in the Grand Union Canal, the Serpentine lake in Hyde Park and Aldenham Reservoir. Their abundance is causing problems for anglers as the crayfish often take the bait before the fish.

In the mid-1970s the North American signal crayfish, *Pacifastacus leniusculus* (Dana), was introduced into England for aquacultural trials. Due to the success of these it has been widely distributed since then and over 300 sites have been stocked in England and Wales. As with the narrow-clawed crayfish, some have escaped or been deliberately introduced into the wild where they now form large rapidly expanding populations, again causing problems for anglers. The signal crayfish is a highly fertile, aggressive, invasive species. Consequently, as it spreads into new areas, other crayfish are usually eliminated, probably by competitive exclusion, predation or disease (see section on Crayfish plague).

The noble crayfish, *Astacus astacus* (L.), has also been introduced into England from mainland Europe and has flourished in a number of enclosed sites. Although not as aggressive as the signal crayfish, this species has similar characteristics and could be expected to be a serious competitor for resources if it were to mix with native populations.

The most widely introduced crayfish globally, *Procambarus clarkii* (Girard), the red swamp crayfish, has found its way into Britain via the aquarist and restaurant trades. This prolific, burrowing North American crayfish has caused environmental problems in many countries. It has been found in the wild but it is not known whether it can breed successfully in Britain.