WHITE-CLAWED CRAYFISH, *AUSTROPOTAMOBIUS PALLIPES*, IN THE RIVER TONE: CURRENT STATUS AND PROJECTIONS

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SUMMARY

This paper outlines the status, past and present, of crayfish in the river Tone. The nature and the importance of the role played by the white-clawed crayfish, *Austropotamobius pallipes*, in riverine ecology is discussed, together with the reasons for its decline in the UK in recent years. This is placed in the context of a survey of the river Tone implemented in 1996, which failed to identify the presence of any native crayfish but did locate two populations of the exotic signal crayfish, *Pacifastacus leniusculus*. A follow up study to establish if the catchment is infested with the crayfish disease, *Aphanomyces astaci*, was negative. The implications of these findings are discussed along with the prospects for the re-introduction of *A. pallipes* if required.

KEYWORDS

Crayfish, native, exotic, plaque, river Tone, conservation.

ECOLOGY

Classification and Habitat

Crayfish are classified in the order Decapoda of the class Crustacea. More than 500 species occur worldwide and these are divided into two major families: the Astacidae (the 'old-world' crayfish) and the Cambaridae (the 'new-world' crayfish). The Astacidae, to which all European crayfish belong, exhibit a limited degree of adaptive radiation: they are very similar in their ecological requirements (Hobbs, 1988).

Only one species occurs naturally within the British Isles, the white-clawed crayfish, *Austropotamobius pallipes* (Lereboullet) (*see* Fig. 1). Until the recent introduction of exotic crayfish, *A. pallipes* was our largest mobile freshwater invertebrate. It was formerly a common inhabitant of the lime-rich waters of England (Brown & Bowler, 1976). Its range is restricted to neutral to alkaline (pH7 to pH9) waters and, as with all crayfish species, the calcium ion concentration must be in excess of 5mg/l. The species is largely nocturnal. It can be found in a variety of water bodies ranging from fast-flowing streams to still lakes, but each location must offer sufficient refuges in the form of stones, debris, or tree roots. Animals will dig burrows in the sediment of the bank or bed, but they avoid areas of high

turbidity. Water quality is important: the majority of records for the species are from Class 1A and 1B waters (Mason, 1990). *A. pallipes* also avoids very cold areas, such as those found in the vicinity of springs (Laurent, 1988). It requires summer temperatures in excess of 10°C (Brewis & Bowler, 1983). Like most crayfish species, *A. pallipes* will occasionally venture out of water to migrate or feed (Holdich, 1991). Populations in rivers typically occur in densities of three to seven crayfish per square metre (Laurent, 1988).

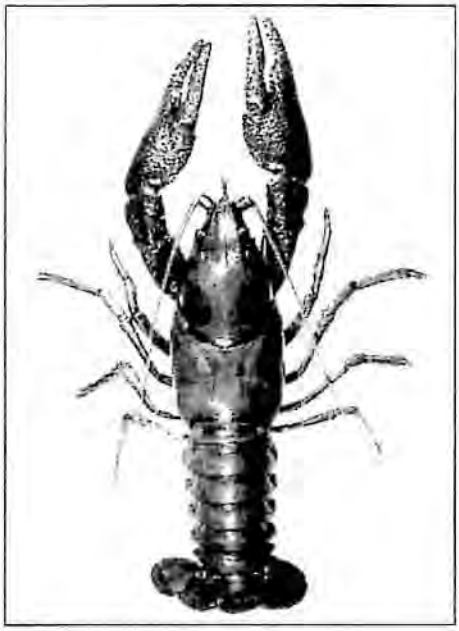

Fig. 1 The white-clawed crayfish, *Austropotamobius pallipes*.

Reproduction and Growth

The native crayfish generally attains sexual maturity in the fourth year, when males have reached a carapace length of 33 mm and females 28 mm (Lowery, 1988). Mating takes place in October or November when the male deposits a spermatophore on the ventral surface of the female. The eggs are laid and fertilised externally and the egg mass is mounted on the pleopods of the tail by an adhesive secretion. The 'berried' female carries this load into the spring of the following year. Unlike other members of Crustacea (e.g. crabs and lobsters) there is no free-living larval stage. The young hatch in May or June, but remain attached to the female for three successive moults. During this period the young utilise their egg yolk whilst developing the setae of their mouthparts (Thomas, 1973). They assume an independent existence when the carapace length attains 3.5 mm. During their first summer, the young typically undergo seven or eight moults, but this growth is temperature dependent. Animals exhibit little or no growth below 10°C and over-winter in a quiescent state. The number of moults declines over successive summers, falling to only one in the fourth or fifth years (*see* Table 1). Ovigerous adult females are restricted to one moult per year because they cannot moult whilst carrying eggs or young. Consequently, male crayfish are able to grow larger than their female counterparts.

Ecdysis is a critical period of the animal's life history. The shedding of the hard exoskeleton leaves them vulnerable to predation, including cannibalism. Moulting animals

are trap-shy at these times and it is difficult to locate them, even at night. There is evidence that adults synchronise their moults as a survival strategy and these moult periods may last for several days (Pratten, 1980). Further stresses occur with the loss and replacement of calcareous material. Only 10% of the calcium salts required for a new exoskeleton are conserved in the body; the rest are lost (Greenaway, 1985). This accounts for the dependency of the species on calcareous waters. The loss and replacement of calcium places a serious metabolic burden upon the animal and this probably accounts for a substantial proportion of the mortality which occurs at this time (Lowery, 1988).

TABLE 1. MOULT FREQUENCY OF *A. PALLIPES* IN SOUTHERN ENGLAND (PRATTEN, 1980). IMMATURE ANIMALS MAY MOULT ONCE MORE PER YEAR IN A WARM SEASON. FEMALES OF AGE CLASS 3 CAN ONLY MOULT TWICE IF THEY ARE NOT OVIGEROUS.

Age class	Number of moults		Mean carapace length (mm)
	male	female	
0+	7	7	12.7
1	4	4	20.0
2	2	2	24.3
3	2	2	29.0
	maturation		
4	2	1	32.6
5	1	1	35.0
6	1	1	37.6

Trophic Relationships

The white-clawed crayfish, being highly polytrophic, assumes a complex role in lake and riverine ecology. They are variously filter-feeders, detritivores, scavengers, carnivores and herbivores and their preferences alter according to the life stage. There is evidence to suggest that first-year crayfish are obligate filter-feeders. Increased survivorship has been shown amongst crayfish fed on suspensions of the green alga, *Chlorella*, and juveniles are frequently found with a large proportion of diatoms in the hindgut (Mason, 1975; Holdich & Reeve, 1988). A variety of small aquatic invertebrates, particularly worms and snails, form the major component of the juvenile's diet in subsequent years (Holdich, 1991). Adults, by contrast, feed largely on vegetation and plant detritus. Studies have shown that, in the spring, an adult's diet consists predominantly of decomposing leaves, roots and bark. One study revealed a preference for alder leaves, over oak and ash (Mason, 1975). In the summer, submerged plants, such as *Ranunculus*, *Potamogeton* and *Chara*, assume increasing importance in the animal's diet. Submerged vegetation is preferred to emergent plants (Reynolds, 1979). This selective feeding can effectively shape the nature of a watercourse. Elimination of populations can result in profound ecological changes, with increased eutrophication and the over-abundance of aquatic macrophytes (Holdich, 1991).

The crayfish is also an important food source for a wide range of animals (Hogger, 1988). Invertebrate predators, such as dragonfly nymphs, will take young crayfish. Cannibalism is not uncommon amongst stable populations. They can also form a small component of the diet of a large number of fish, including barbel, bullhead, eel, perch, pike and trout. Herons and kingfishers are the major avian predators, though there are records of crows and even tawny owls taking them. Mammalian predators include the otter, brown rat and mink. Crayfish sometimes form a major component of the otter's diet.

THREATS AND DECLINE

Pollution and River Management

A. pallipes is an excellent indicator of good water quality. The native crayfish is a nexus within aquatic food chains and it is perhaps this energy-transforming role which makes the animal so sensitive to chemical water pollution. In the UK, 86% of records of the native crayfish are from Class 1 rivers (Mason, 1990). The native crayfish is particularly vulnerable to biocides and spills from agricultural waste. Pollution incidents involving these have often led to the elimination of populations.

A. pallipes is also affected by poor fencing on agricultural land. A poached bank caused by the hooves of watering livestock markedly diminishes the value of the habitat (Cordrey, 1997). Abstraction may lead to critically low water levels and high stressful temperatures during the summer months. Further threats include dredging and flood alleviation activities such as canalisation and the removal of trees. The latter activity results in both the loss of refuges and the loss of a valuable food source.

Whilst pollution and river management activities have undoubtedly had an impact upon the distribution of the native crayfish, such impacts must be seen as secondary to the impact of exotic crayfish and the crayfish plague. The aforementioned impacts are also, in general, reversible.

Exotic Crayfish

Whilst introductions elsewhere in Europe were leading to local extinctions of native crayfish populations, it is perhaps the conservative nature of the British palate which served to safeguard the UK's populations of *A. pallipes* for close on a century. Although a number of introductions into the UK were attempted prior to the 1970s, these attempts were neither large-scale nor widespread. Consequently they met with little success. Only the Turkish Crayfish, *Astacus leptodactylus*, has become established and this appears to be restricted to lakes within a London park (Goddard and Hogger 1986). It was not until 1976 when a thousand juvenile signal crayfish, *Pacifasticus leniusculus* (Dana), were imported into ponds and farms from the Simontorp hatchery in Sweden that crayfish farming in the UK promised to become a viable industry. In subsequent years further imports were made from Simontorp, elsewhere in Europe and also direct from their native North America.

The pre-eminence of *P. leniusculus* over the native crayfish as a food-source also extends to its ecological fitness. Signal crayfish grow faster and larger than the native crayfish (Fig. 2). They are more aggressive and have a higher fecundity. Signal crayfish are very similar to native crayfish in their ecological requirements, but are more tolerant of pollution and can even survive in the brackish waters of estuaries. They will cause local extinctions of native crayfish populations wherever they become established, through competition, predation and inter-specific matings (Laurent, 1988). Matings between the two species have often been observed but the resulting egg mass shows little sign of development.

The introduction of *P. leniusculus* into the UK was largely uncoordinated, with a lack of controls over holding facility requirements. Consequently, escapes into natural water-courses were inevitable; and were compounded by the animal's ability to travel long distances overland. Introduced *P. leniusculus* can lead to the depletion and elimination of macrophytes, freshwater invertebrates and benthic fish, such as the bullhead *Cottus gobio* (Wiles, 1997), which is listed on Annex II of the EC 'Habitats and Species' Directive (1992). *P. leniusculus* outcompetes bullheads for refuges and can even prey upon them. Populations can also damage fish spawning sites and there are reports of anglers encountering problems with *P. leniusculus* eating their bait and attacking fish in their keep nets (Holdich, 1991).

Fig. 2 Comparative growth rates of *Austopotamobius pallipes* and *Pacifastacus leniusculus* in southern England (Hogger, 1984; reproduced in Lowery, 1988).

Cray fish Plague

Native crayfish are naturally afflicted by a variety of identifiable diseases caused by bacteria, fungi and protozoans (Alderman and Polglase, 1988). 'Porcelain disease' is probably the most easily recognised. *Thelohania contejani*, a microsporidian, can multiply within the body to the point at which it turns the musculature an opaque, china-white colour, like porcelain. Individuals can live with this infection for a number of years but eventually succumb. It is one of the more widespread diseases and, where it occurs, it can infect up to 30% of the members of a population. Other infections include those by chitinoclastic bacteria which cause melanisation of the exoskeleton, a condition known as 'burn-spot' disease. Fungal infections, however, can also lead to melanisation, and this includes *Aphanomyces astaci*, the causal agent of crayfish plague.

No crayfish disease rivals the virulence of *A. astaci*. European crayfish have no immunity to the disease and generally succumb within days of infection. The disease first arose in Europe in Italy in the 1860s, probably brought in on crayfish imported from North America. North American species, such as the signal crayfish, *Pacifastacus leniusculus*, exhibit a balanced pathogen-to-host relationship with *A. astaci*. Since the latter half of the nineteenth century, *A. astaci* has devastated native crayfish populations throughout Europe. Human activity has probably been the major factor in its dispersal. The zoospores cannot survive for long in nature in the absence of a host. They will survive in moist mud for only two weeks. However, fish nets can, whilst they remain damp, transmit infection. In addition, fish have been shown to act as passive carriers for the fungus (Alderman *et al.*, 1987).

Crayfish plague was not reported in the UK until the early 1980s, following the introduction of *P. leniusculus*. The Bristol Avon and the Hampshire Avon were the first catchments reported to be affected (Alderman *et al.*, 1984). Since this time many populations have been eliminated throughout the country, particularly south of the Pennines.

The gross signs of plague are very variable (Alderman & Polglase, 1988). The speed with which infection and mortality occur is dependent upon the water temperature and the

abundance of zoospores. When large numbers of zoospores are present the host's defences are overwhelmed rapidly and death occurs with few indications as to the cause, except perhaps some whitening of abdominal musculature. In slow-kill infections, by contrast, brown melanisations occur on the exoskeleton and these are accompanied by the whitening and necrosis of underlying musculature. Such chronic infections are often accompanied by secondary bacterial infections. Even apparently healthy animals removed from an infected population die within 7 days at 16° C (Alderman *et al.*, 1984). Fungi can sporulate in the early stages of infection. Consequently, an initial slow-kill infection in a population may lead to a rapid-kill as many more zoospores are released into the waters.

Behavioural changes also occur in the latter stages of infection (Alderman *et al.*, 1984). Moribund animals can be found out in the open during daylight hours and exhibit slow, uncoordinated limb movements, often appearing to walk 'on stilts'. Individuals will also exhibit weak tail flip escape reflexes with a tendency to roll over and lie helpless.

LEGISLATIVE FRAMEWORK

Europe

The world status of *Austropotamobius pallipes* is given as 'rare' by the International Union for the Conservation of Nature (IUCN) (Wells, Pyle and Collins, 1983) and 'vulnerable' in Europe (Collins and Wells, 1987), largely as a result of the impact of crayfish plague. It is listed in Appendix III of the Bern Convention and Annexes II and V of the Directive 92/43/EEC on the conservation of natural habitats and of wild flora and fauna (the 'Habitats and Species' Directive). Appendix III of the Convention and Annex V of the Directive detail species where exploitation should be subject to appropriate control in member states. Designation of protected areas is required for species on Annex II of the Directive.

The United Kingdom

A. pallipes is listed on Schedule V of the Wildlife and Countryside Act 1981 which prohibits taking the animal from the wild and its sale. A licence is required from English Nature in order to remove *A. pallipes* from the wild for such purposes as scientific research, conservation, photography or education. Schedule 9 of the Wildlife and Countryside Act lists three non-native crayfish: *Astacus astacus, Astacus leptodactylus* and *Pacifastacus leniusculus*. This makes it an offence under Section 14 of the Act to release these species or to allow them to escape into the wild and states that 'reasonable steps' and 'due diligence' must be exercised to prevent escape. It is also an offence to release other crayfish species not ordinarily resident in the UK in a wild state. The Ministry of Agriculture, Food and Fisheries (MAFF) is the licensing authority for the farming of crayfish. This legislation satisfies the requirements of Appendix III of the Bern Convention and Annex V of the 'Habitats and Species' Directive.

In order to fulfil the requirements of Appendix II of the 'Habitats and Species' Directive a number of areas have been identified in the UK where the keeping of live crayfish is prohibited (no-go areas) under the Keeping of Live Fish (Crayfish) Act of 1996. However, the no-go areas can be inadequate, since they were formulated not on the basis of catchment areas but postcodes. The river Tone as a whole does not comprise part of the protected areas because of known non-native crayfish populations within the catchment area. However, the postcodes TA3, TA4, TA2O, TA21, TA22, TA23 and TA24 do form part of the South West exclusion area.

A number of species action plans have been written for the native crayfish. The JNCC Report (Palmer, 1994) identified the need for continuing monitoring and research, for the implementation of 'no-go' areas, for effective containment measures for non-native crayfish

and, where possible, their eradication. The Biodiversity Challenge Group (1995) reiterated these proposals in the UK Biodiversity Steering Group Action Plan. *A. pallipes* has also been placed on English Nature's Species Recovery Programme. It identifies the need to review the impact of increasing fishery and to assess the distribution, status and habitat requirements at selected sites. A species action plan for *A. pallipes* has also been drafted for inclusion in the South-West Regional Biodiversity Initiative (Cordrey, 1997). Two objectives are outlined: to ensure the survival of the present populations and to re-introduce the native crayfish "to suitable waters where appropriate". In Somerset, the Mendip District Council Biodiversity Action Plan (SERC, 1995) has taken the lead in drawing up a Species Action Plan for the District, but this has yet to be replicated elsewhere in the county.

THE STATUS IN THE RIVER TONE

Pre-1996

An electro-fishing survey carried out along the river Tone by the National Rivers Authority in 1994 found that the distribution of the native crayfish extended from Washbattle Bridge (ST 053285) to Tonedale Bridge (ST 120217). Only the major adjoining tributaries were surveyed. The Somerset Environmental Records Centre (SERC) holds records of native crayfish for the river Tone dating back to 1960. These records concur with the distribution reported by the NRA. The river Tone has a high water quality with low levels of organic pollutants and high levels of dissolved oxygen. The General Water Quality Assessment Classification varies from 1A to 1B between Clatworthy and Runnington. The catchment lies on sandstone and clay. Measurements taken by the Environment Agency show appreciable levels of calcium ions, typically in the region of 10 to 50 mg/l. The pH of the water varies from 7.1 to 8.1. Alternate pools and riffles are characteristic throughout, with a mixed substrate of pebbles and soft sediment. Much of the bank is stabilised by tree roots.

The nature of the water course and the abundance of the native crayfish led David Holdich of Nottingham University's national crayfish database to conclude that the Tone possibly contained the only sustainable and effective population remaining in the former Wessex Region of the NRA (Farr-Cox, pers com.). However, the consultation report for the river Tone catchment management plan (NRA, 1995) reported an introduction of alien crayfish into the catchment area and, consequently, the report's prognosis was pessimistic. It concluded that the eradication of *Austropotamobius pallipes* from the Tone as a result of disease, competition and predation was inevitable.

1996 Survey Method

The 1996 survey sought to determine the current distribution of all crayfish species within the river Tone catchment area as the basis for a conservation strategy. During the summer of 1996, six sites were surveyed along the Tone, and a further six sites in associated tributaries. Four 'trappies' were used at each selected site and these were baited with fish waste from a local fishmongers. The traps were re-baited daily and were left in place for at least three successive nights. Wherever possible the traps were placed in tree-shaded pools with rocky substrates: areas most likely to be favourable for crayfish. Stones were also overturned at sites in an attempt to locate crayfish. Care was taken to prevent the accidental spread of the crayfish plague zoospores on the trapping equipment. For this reason each new survey site was located downstream of previous sites, whenever possible. Where this proved impractical, the traps were chemically treated with FAM 30 iodophor disinfectant to kill any attached spores.

Survey Results and Discussion

The surveyed sites and results are presented in Table 2 and Fig. 3. All crayfish species appear to be absent from the river Tone, including all sites from which there are previous

records. Furthermore, a cursory survey of selected tributaries suggests that the native crayfish is extinct from the whole catchment area. Natural fluctuations in population sizes have been observed in populations in the past (Holdich, 1991) and it is possible that this survey coincided with a natural population crash. There is also the possibility that crayfish at any one site were undergoing a moult at the time of survey. Since moulting crayfish are trap-shy and adults can synchronise ecdysis. This could further reduce the trapping success rate. However, the traps were in place within the known former range of *A. pallipes* for more than eighteen nights. Given that populations generally occur at densities in excess of three per square metre it seems improbable that the survey could have failed to uncover a resident population. It is possible, however, that vestigial populations are present at Clatworthy or along minor tributaries which were not surveyed in this study or in the past. An electro-fishing survey to be carried out in the river Tone and its tributaries in the summer of 1997 by the Environment Agency may clarify the situation. However, this is not a crayfish-specific survey. It therefore seems advisable for SERC to employ a tested alternative survey method (i.e. night searches) to complement the electro-fishing survey.

Only signal crayfish, *Pacificastus leniusculus*, were found to occur within the catchment area. Two populations were identified, in ponds at Jew's Farm and Woolcombe. Communication with the landowners suggested that the Woolcombe population was established in the late 1980s and the Jew's Farm population around 1990. The population at Woolcombe is well-established and has begun to disperse along the connecting tributary towards the river Tone. Only one crayfish was captured at Jew's Farm pond over three days, suggesting a small population. The site exhibits signs of eutrophication and it is likely that the introduction failed to produce a breeding population. Since no crayfish were found in the Tone itself the disappearance of the native crayfish population cannot be accounted for through inter-specific competition. No significant pollution incidents have occurred in the upper reaches of the Tone over the last three years. The implication, therefore, is that crayfish plague from one or both of the *P. leniusculus* populations has led to the elimination of *A. pallipes* in the Tone.

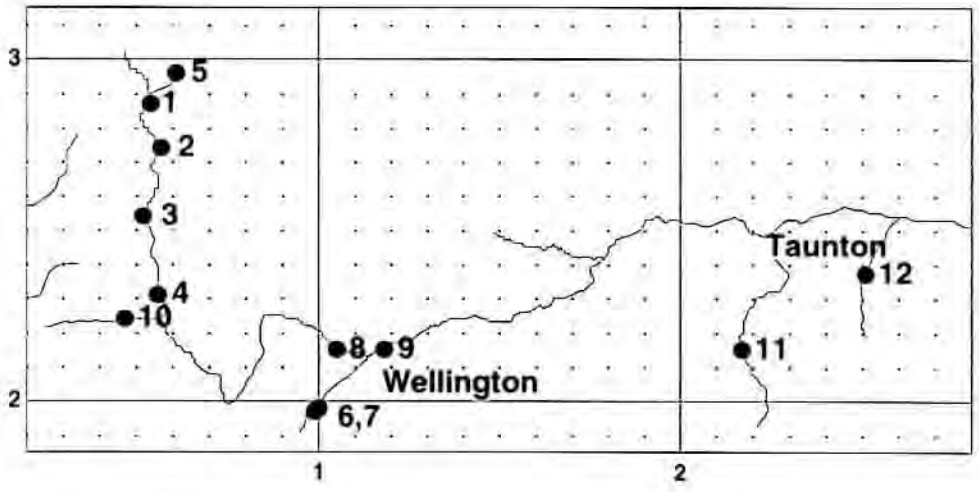

Fig. 3 and Table 2. (See next page).

Site number and name	Grid reference	Recorded crayfish
1. Washbattle Bridge (Tone)	ST 054 287	absent
2. Marsh Ball (Tone)	ST 057 274	absent
3. Waterrow (Tone)	ST 052 254	absent
4. Burrow Farm (Tone)	ST 056 231	absent
5. Jew's Farm (pond)	ST 061 296	*Pacifastacus leniusculus*
6. Woolcombe (pond)	ST 099 197	*Pacifastacus leniusculus*
7. Woolcombe (tributary)	ST 100 198	*Pacifastacus leniusculus*
8. Harpford Bridge (Tone)	ST 105 215	absent
9. Runnington (Tone)	ST 118 215	absent
10. Pool Farm (tributary)	ST 047 224	absent
11. Sherford Stream (tributary)	ST 217 215	absent
12. New Barn Farm (tributary)	ST 251 237	absent

Fig. 3 and Table 2. Crayfish trapping sites and species recorded along the river Tone and its tributaries in the summer of 1996.

1997 CANARY CAGE EXPERIMENT

Method

The 1996 survey of the Tone suggested that the native crayfish is now extinct in the catchment area and that the probable cause is crayfish plague. The purpose of this experiment was to test the theory of probable cause and determine the feasibility of a proposed re-introduction of the native crayfish into the Tone.

Although the fungal infection, *Aphanomyces astaci*, has been isolated from the signal crayfish, *Pacifastacus leniusculus* (Alderman & Polglase, 1988) the procedure is a difficult one. Consequently, the accepted method for testing a water-course for crayfish plague is through the use of 'canary cages' containing uninfected native crayfish.

Two fine-mesh cages were obtained measuring 400 × 600 × 200 mm. These cages were placed in the river Tone in January 1997 at Washbattle Bridge (ST 054287) and Runnington (ST 118215) and set in place by an attached chain and stake lodged firmly into the river's bank. Care was taken to ensure the cages could be lifted out onto the bank without removing the stake. The selected sites were located immediately below the two tributaries in which the alien crayfish populations were known to occur. Approximately twenty pieces of plastic tubing were placed in each cage as refuges for the crayfish.

Once the cages were established in the Tone, twenty adult native crayfish were collected from the Sherston Avon in Wiltshire (ST 852856). Males were preferred since females are 'berried' during the winter and would therefore release young into the river in the spring. Ten animals were introduced into each cage in late January. Each cage was then checked on a weekly basis and the water temperature recorded on each occasion. The Washbattle Bridge cage, located upstream from Runnington, was checked first on each occasion to prevent cross-contamination. The animals were supplied with food in the form of decaying leaves and submerged vegetation. Additional food in the form of carp pellets was supplied as the animals became more active in the warmer spring temperatures. It was anticipated that infestation was most likely to occur as temperatures began to rise in the spring, but a period of six months is required to be certain of a negative result in the event of a low challenge rate (Frayling, pers. com.).

Natural deaths of one or two individuals were anticipated in the course of the experiment. In the event, replacements would be obtained from Sherston Avon. Should suspected deaths

from plague occur then the animals would be preserved in formaldehyde or alcohol and sent to Dr. D.J. Alderman (Fish Diseases Laboratory, MAFF, The Nothe, Weymouth, Dorset DT4 8UB) for analysis. Freshly dead or moribund animals are best for analysis.

Results and Discussion

The experiment failed to produce any suspected cases of plague in the canary cage populations in the six month period. This provides strong evidence against the theory of extinction by means of one or both of the signal crayfish populations in the catchment acting as vectors for the fungus *A. astaci*.

Such a conclusion points to three alternative theories:

1. The extinction of the native crayfish resulted from an alternative, transient vector. This may have been from fishing tackle or from the feet of a bird infected in another water-course. The fungus could then have gone extinct itself following the demise of the host. Transfer of the spores from the river Tone to the two signal crayfish populations would not be inevitable since the spores could not move unaided against the currents of the relevant tributaries.
2. The 1996 survey failed to identify a residual population in the river Tone and/or its tributaries.
3. An as yet unidentified causal factor led to the decline and extinction of the native population in the Tone.

Combinations of the theories are plausible. The third theory is unlikely for reasons presented earlier: the Tone has an unbroken recent history of good water quality and no other highly virulent crayfish diseases are known. It is possible that a population still exists in the Tone which the 1996 survey failed to locate since any extinction is very difficult to prove unequivocally. Consequently, a tested, alternative survey method (night searches) should be carried out in the summer of 1997 to lend further weight to the apparent status. Crayfish are active mainly at night and their eyes reflect torch-light very effectively.

In conclusion, the initial results suggest re-introduction is a feasible option, but further survey work is required to demonstrate that, due to extinction, it is a necessary one.

METHODS AND OBTACLES FOR THE REINTRODUCTION OF NATIVE CRAYFISH

Eradication

Any re-introduction of native crayfish into the river Tone must be preceded by the elimination or control of the signal crayfish populations. Unfortunately, there is at present a lack of effective methods for eliminating signal crayfish from the wild. Although biological controls have been employed (Soderhall *et al.*, 1977), these are widely seen as ineffective (M. Frayling, pers. com.). Trapping is a labour-intensive procedure and may only serve to contain a population. Well-established populations are probably impossible to eradicate, but the two populations in the Tone catchment are still quite restricted and if recruitment into the river Tone can be prevented, re-introduction could proceed. Observations from other water-courses suggest that signal crayfish range expansion occurs incrementally not spasmodically (Wiles, 1997). Crayfish washed downstream do not appear to establish viable populations. The veracity of this observation is vital if the populations of *P. leniusculus* in the Tone catchment are to be contained and eliminated.

The signal population at Jew's Farm appears to be in decline and is unlikely to present a threat. The population at Woolcombe by contrast has proceeded to disperse down the tributary towards the river Tone. It is vital that this population in the tributary is eradicated.

This is important not only for the prospects of re-introduction or the protection of possible residual native crayfish populations, but to safeguard the ecology of the river as a whole.

The extent of signal crayfish dispersal along the Woolcombe tributary is unclear. It is therefore difficult at this stage to estimate the length of time required to eradicate the population, but it may take a number of years. Trappies should be situated at short intervals along the length of the tributary. Modifications to the traps are required to ensure that all age classes can be caught. Captured crayfish can be destroyed by freezing, a painless procedure recommended by the RSPCA.

Containment

Elimination from the pond itself would be more problematical, since the population is so well established. Additionally, the owner would be reluctant to agree to the eradication of the signal crayfish, which he farms for his own table, even with the promise of compensation. It is unfortunate that the protected status of the native crayfish has removed any possible economic value. Although they are less attractive as a food item, a more flexible protected status could encourage conscientious epicures to farm native crayfish instead of signals.

Containment within the Woolcombe pond may prove to be the only option. Guidelines for the containment of crayfish farms have been laid out by MAFF (Alderman & Wickins, 1996). Unfortunately, the aforementioned pond both gives and receives water from the nearby tributary. Alderman and Wickins recommend the use of plastic or wire mesh over outlets and inlets with an inwardly-directed overlap at the top, but very small juveniles may still be able to escape. Two types of terrestrial barrier are suggested. Earth banking up to one metre high, or smooth rigid sheeting at least 25cm high, sunk into the ground. For the latter to be effective vegetation must be kept mown down, otherwise crayfish will use it to climb over the barrier.

Re-introduction

Although there is little literature on re-introduction programmes in the UK there have been a number of success stories, such as the re-introduction of *A. pallipes* to the Sherston Avon, (Frayling, pers. com.). These re-introductions have involved transferring members of a wild population to target sites. However, a captive breeding programme for native crayfish was initiated recently by Adrian Hutchings of Sparsholt College, Hampshire, and it is preferable for future re-introductions to utilise this or an alternative captive programme.

Alderman and Wickins (1996) recommend a phased introduction over three to five years, at the rate of approximately three juveniles per metre of river bank per year to achieve a good age mix. The population should be monitored closely to establish the point at which a self-producing population has been established. No further introductions should then be carried out to prevent the risk of introducing disease.

Conclusions

1. The results of the 1996 survey suggest the native crayfish may be extinct in the river Tone. Two populations of *leniusculus* were located in private ponds within the catchment area, with one of these populations at Woolcombe (ST 099197) showing signs of dispersal and posing a serious ecological threat to the river Tone
2. Two canary cages were placed in the Tone in early 1997 to determine if the disappearance of the native crayish was due to *A. astaci* spores from one or both of the *P. leniusculus* populations. Results suggest the *P. leniusculus* populations are not infected with the fungal disease.
3. The absence of records of native crayfish in the 1996 survey may be due to fungal infection from a transient source no longer present within the catchment.
4. Three recommendations stem from this work:
   i. An alternative tested survey method is required to confirm the complete absence of *A. pallipes* from the Tone catchment or identify any residual populations.

ii. Attempts need to be made to erradicate any dispersing signal crayfish within the Woolcombe tributary. This process could take a number of years.

iii. The population within the Woolcombe pond should also be eliminated if possible, or contained with the aid of aquatic and terrestial barriers. Constant monitoring will be required if the latter option is to be successful.

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