Guidance on Habitat for White-clawed Crayfish

ENGLISH NATURE

species RECOVERY

ENVIRONMENT AGENCY

Guidance on Habitat for White-clawed Crayfish
and its Restoration

Stephanie Peay

July 2002

Stephanie Peay
15A Longwood Avenue
Bingley
West Yorkshire
BD16 2RX

Telephone: 01274 511637
Email: crayfish@brydens.org.uk

This report has been prepared for English Nature and the Environment Agency as part of the Species Recovery Programme.
It constitutes Environment Agency Technical Report W1-067/TR

ISBN: 1844320820

Project manager for English Nature:

Maggie Robinson
English Nature
Juniper House
Murley Moss
Oxenholme Road
Kendal
Cumbria
LA9 7RL
01539 792800

Project Manager for the Environment Agency

Julie Bywater
Environment Agency
Lambourn House
Howbery Park
Wallingford
Oxon
OX10 8JL

All photographs are by the author, except for illustrations 13a/b and 14 a/b and in River Leith case study, which were kindly provided by Alisdair Brock, Eden Rivers Trust, Cumbria.

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1. Purpose of this Manual

The aim of this manual is to give guidance on habitat management strategies for the white-clawed crayfish.

It is likely to be relevant to statutory agencies such as the Environment Agency and English Nature; landowners and occupiers; fisheries managers; engineering and environmental consultants and contractors.

The white-clawed crayfish (*Austropotamobius pallipes*) is the only native species of freshwater crayfish in Britain and the largest freshwater crustacean. Although locally abundant in some areas of England and Wales, the white-clawed crayfish has declined dramatically in recent years. It is under threat throughout its range in Britain and in other areas of Europe. The principal causes of decline are competition from non-native crayfish and a lethal disease (crayfish plague) carried by introduced species.

Habitat deterioration and loss can also have significant impacts on remaining populations. Maintenance and enhancement of habitat forms an important part of the conservation strategy for white-clawed crayfish. The strategy is contained in the UK Biodiversity Action Plan for white-clawed crayfish (Palmer, 1994 and DoE, 1995).

Guidance in this document includes:

- white-clawed crayfish, its status and protection (section 2);
- requirements of white-clawed crayfish (section 3-5);
- assessing the scope for improving habitat (section 6 and 8);
- habitat restoration and management techniques (section 7 and Appendix 1 case studies).

Further guidance on white-clawed crayfish is available from the Environment Agency or English Nature, who will help to obtain specialist advice if necessary.

2. White-clawed Crayfish, its Status and Protection

2.1 Legislation and Policy

The white-clawed crayfish is referred to in various pieces of legislation and policy. These instruments include:

- Bern Convention Appendix III Priority Species;
- IUCN Red Data List for Endangered and Threatened Species, category Globally Threatened;
- EC Habitats Directive Annex II and V;
- Wildlife and Countryside Act 1981 as amended, Schedule 5;
- Countryside and Rights of Way Act (2001);
- Conservation (Natural Habitats &c) Regulations 1994;
- UK Biodiversity Action Plan, Priority Species.

These all recognise that the white-clawed crayfish is a species under threat and in need of protection and conservation.

The white-clawed crayfish is listed under Annex II and V of the EC Habitats Directive, implemented in the UK by the Conservation (Natural Habitats &c) Regulations 1994. Annex II requires that Special Areas of Conservation (SAC) are established specifically to conserve this and other listed species. In SAC designated for white-clawed crayfish a precautionary principle must be applied when considering the potential impacts of any operations that may affect white-clawed crayfish and their habitat.

Several organisations involved in works on rivers, or other water bodies have general legal obligations to further the conservation of flora and fauna. These include the Environment Agency, water companies, internal drainage boards, local planning authorities and the Department of Environment Food and Rural Affairs (DEFRA).

These agencies are all required to take the needs of species of high conservation priority into account. In respect of white-clawed crayfish and river works, this can be achieved, in part, by following the guidance in this document and in the companion publication "Guidance on Works Affecting White-clawed Crayfish (Peay, 2001).

2.1.1 Regulations on Alien Crayfish

The Prohibition of Keeping Live Fish (Crayfish) Order 1996 was introduced to help to prevent the release of crayfish into the wild. The definition of "the wild" has been made much more stringent for crayfish than for fish – in recognition of the ability of the American signal crayfish (*Pacifastacus leniusculus*) to escape and survive out of water. In addition to rivers and lakes, ponds in gardens, farms and fish-farms all constitute "the wild" (Stewart, 2000).

There is a ban on keeping alien crayfish in all parts of England, Wales and Scotland, except under licence. The exception is the keeping of signal crayfish in some areas of southern England and eastern Wales, where there were a lot of escaped populations prior to the Order. A licence to keep alien crayfish may be granted by the Department of the Environment, Farming and Rural Affairs (DEFRA) at premises that are escape-proof, for example in laboratories for research purposes. The prohibition on keeping crayfish does not apply retrospectively to places where they were kept prior to the Order. The few crayfish farms operating in prohibited areas were given licences of right to continue to keep signal crayfish. Such sites remain potential sources of crayfish plague and colonisation by alien crayfish.

2.1.2 Crayfish and the law

Additional details on legal issues are given in Table 2.1.

Table 2.1 Crayfish and the Law

Instrument	Provision
Wildlife and Countryside Act 1981, as amended	Under Schedule V it is illegal to take or sell white-clawed crayfish. Section 16(3) allows English Nature (EN) or Countryside Council for Wales, (CCW) to issue licences for conserving the species. Licences may be issued for rescue operation in relation to maintenance or engineering works only if the activity is properly planned and executed and thereby contributes to the conservation of the population. Under Schedule 9 it is an offence to release or allow to escape any pest species listed. The signal crayfish is one of the alien species of crayfish listed. Measures are required to avoid introduction or spread of this species and other alien crayfish. Any caught during works on waterbodies should not be put back in the wild.
Countryside and Rights of Way Act 2001	For water bodies notified as Sites of Special Scientific Interest (SSSI), consent or assent will be required from EN or CCW to undertake any activity listed in the 'Operations Likely to Damage the Special Interest' of the site. Where proposed works require consent from the Environment Agency (EA), an Internal Drainage Board (IDB) or other statutory agency, the authority must consult and take the advice received from EN or CCW into account when deciding whether to permit the proposed operation, or if any conditions should be attached to the permission.

In summary:

- Surveys for white-clawed crayfish should only be carried out under licence. Licensing bodies are English Nature and Countryside Council for Wales. In Northern Ireland the Natural Heritage section of the Environment and Heritage Services provides licences for surveys of protected species.
- It is illegal to allow alien crayfish to escape into any waterbody or watercourse.

2.2 Requirement for Consultation

Under the Water Resources Act 1991, the Environment Agency has powers to create byelaws whereby formal consent is required for any works within a certain distance of a main river bank or floodbank (usually 8 or 9 metres).

Under the Land Drainage Act 1991, consent is also required for any works that affect the flow in watercourses that are not classified as main river. The Environment Agency is the authorising body in England and Wales, except on watercourses that are under the control of an Internal Drainage Board. The local Environment Agency office will usually be the first point of contact when planning works. Works not only include construction and excavation, but also other activities that may affect the floodplain, such as planting new woodland. In Northern Ireland the Rivers Agency of the Department of Agriculture and Rural Development deals with rivers.

If work is proposed on a river or other water body within a SSSI or SAC, consent is required from the local office of English Nature, or the Countryside Council for Wales. The Environment Agency will be able to tell you if this is the case.

Appendix 1 gives the licensing authorities for protected species in England Wales and Northern Ireland, plus the web-sites that provide addresses for the local offices.

Action involving the "taking" of white-clawed crayfish (essentially, anything involving catching or handling of crayfish) will require a licence. This includes:

- surveys;
- rescuing of individual crayfish prior to works, and
- transfer of white-clawed crayfish from one site to another.

2.3 Distribution of White-clawed Crayfish

Populations of white-clawed crayfish are under threat throughout their European range from:

- crayfish plague, a disease carried by several species of alien crayfish;
- competition from alien crayfish;
- loss of habitat, or reduction of habitat quality, including
- reduction in water quality and pollution incidents.

All of these factors are operating throughout the range of white-clawed crayfish in Britain. This is leading to a major decline in number of sites where white-clawed crayfish occur. Records of the known distribution of white-clawed crayfish are held by the national Biological Records Centre and regionally by the Environment Agency.

The species is still widely distributed in much of the country, (Sibley *et al*, 2002). There are some areas of central and northern England where the white-clawed crayfish is still relatively abundant. There are, however, a rapidly diminishing number of river catchments which have white-clawed crayfish but not signal crayfish. Most of these rivers are in Cumbria and other areas of northern England, although there are small catchments elsewhere which appear to be free of alien crayfish so far. The majority of catchments that support populations of white-clawed crayfish also have alien crayfish living wild in one or more parts of the catchment.

The south-west of England has no records for white-clawed crayfish further west than East Devon. West Wales and Scotland also appear to lack white-clawed crayfish, largely due to the upland character and naturally higher acidity of the river network. White-clawed crayfish have been introduced to two sites in Scotland (Maitland 2001) and there are also signal crayfish in some catchments. White-clawed crayfish occur in Ireland, where populations are strongly associated with the areas that have underlying calcareous rock. There are currently no known populations of alien crayfish in Ireland.

Environment Agency (1999) gives guidance on identifying species of crayfish.

2.4 Key Points on the Status of White-clawed Crayfish

- **The white-clawed crayfish is a species under threat in Britain. This is recognised in a range of national and European legislation and policy.**
- **Where white-clawed crayfish are known to be present, or may be so, any management works or river improvements should take into account the needs of white-clawed crayfish.**
- **Plan for protection of white-clawed crayfish from the start of a project.**
- **Consult the Environment Agency for advice in England and Wales, or in Northern Ireland the Rivers Agency.**
- **If the water body is a SSSI or adjacent to one, consult English Nature, Countryside Council for Wales or Natural Heritage Section of Department of Environment (Northern Ireland) as well.**
- **Obtain a licence from English Nature or the other country agencies for crayfish surveys and for any transfer of crayfish between sites.**

3. Requirements of White-clawed Crayfish

The basic requirements for the survival of white-clawed crayfish are:

- suitable habitat for refuges;
- food supply;
- access to other crayfish for breeding;
- suitable water quality;
- freedom from competition by alien crayfish, and
- freedom from disease carried by alien crayfish.

All of these factors are important in determining whether white-clawed crayfish can survive. Lack of one or more of these requirements can prevent the colonisation of waterbodies by white-clawed crayfish, or lead to loss of existing populations.

Good habitat (including refuges, food supply and favourable water quality) is vital for a healthy population of crayfish. Nonetheless, all the factors need to be considered when planning a conservation project for white-clawed crayfish. This section provides a brief discussion of each of the requirements. Additional detail on habitat requirements is given at the end of this section.

3.1 Suitable Habitat for Refuges

Why Crayfish Need Refuges

White-clawed crayfish of all ages need refuges. Juvenile crayfish are especially vulnerable to predation by fish, ducks and other water birds, otter and mink, carnivorous dragonfly larvae and other predatory invertebrates, including adult crayfish (e.g. as described by Hogger, 1988, Hill & Lodge, 1994).

Adult crayfish use their large front claws (chelae) in defence against fish, but are still vulnerable to some fish species, such as perch and eels, as well as to birds such as herons. Birds and fish tend to be active by day. Crayfish avoid predation by being most active at night, although they can show some activity during daylight (Barbaresi & Gherardi, 2000).

Crayfish are vulnerable to high flows in watercourses. They can be washed away from favourable habitats and stranded, crushed or eaten.

Crayfish are highly vulnerable to predation when they moult. Older adults tend to moult only once a year, whereas juveniles may moult 7 or 8 times in the first growing season (Pratten, 1980).

General Characteristics of Refuges

Crayfish will use a variety of natural and artificial refuges, depending on the habitat available. Broadly individuals select refuges which are:

- fully submerged, although they can survive short periods (hours) uncovered, in damp conditions;
- big enough to amply cover the crayfish, but not too “roomy” for the size of animal;
- stable, or relatively resistant to regularly occurring high flows;
- adequately aerated, and
- available for occupation.

Availability of refuges can be a limiting factor for white-clawed crayfish. Certainly, a lack of favourable habitat is associated either with absence of crayfish, or population densities too low to detect with conventional survey methods (Foster, 1995; Smith *et al*, 1996).

These requirements are discussed further in section 4.

3.2 Food

White-clawed crayfish can feed on a wide range of food, including:

- leaf litter from trees and other plants, after it has soaked for several days;
- aquatic macrophytes, including filamentous algae;
- any aquatic invertebrates slow enough to be caught;
- other crayfish;
- dead fish or other animal remains, and
- small live fish (occasionally).

In most semi-natural habitats, food is not likely to be a limiting factor for the presence of crayfish if other conditions are suitable. Nonetheless, there may be competition for food if the population reaches a high density.

3.3 Contact within a Population

Habitat can be a factor in isolating populations. A feature in a reach of watercourse may form a partial, or even a complete barrier to the movement of white-clawed crayfish, for example:

- a major weir, dam or waterfall;
- a length of highly modified channel lacking in suitable habitat;
- a fast-flowing flume or culvert;
- a dried-up section of channel, or
- poor water quality in a reach.

It is extremely difficult to detect whether a feature is a physical barrier to white-clawed crayfish. In general, we cannot detect populations at very low density in surveys. The survey method developed for the monitoring protocol for white-clawed crayfish (Peay, 2002) provides the best method that is currently available for detecting populations at low abundance, but even this will not consistently detect populations of 1 per $5m^2$ or less.

Barriers and signal crayfish

Note that even if a feature is a barrier to white-clawed crayfish, it will not necessarily prevent the movement of signal crayfish. Signal crayfish can (and do) walk over land. A recent radio-tracking study in the River Ure confirmed that a female signal crayfish travelled at least partially overland from the main river into a drainage ditch, covering a distance of over 30m (D. Bubb, Durham University pers. comm., Environment Agency R&D project WI –074).

Signal crayfish are much tougher than white-clawed crayfish and can survive for weeks to months out of water (e.g. Holdich *et al* 1995). Colonisation of rivers and other waterbodies by signal crayfish is a major concern for the conservation of white-clawed crayfish.

3.4 Suitable Water Quality

White-clawed crayfish occur in a wide range of waterbodies, with quite different physical and chemical characteristics. There are a few general characteristics of water suitable for the species:

- **adequate oxygen**, generally more than 60% saturation of dissolved oxygen and many sites have >80% (Dissolved Oxygen percentage saturation, 10 percentile);
- **no extremes of pH**, generally pH 6.8-8.6, populations are unlikely to occur below pH 6.0;
- **calcium** for growth of the carapace, generally well over 5mg l^{-1} Ca
- **absence of toxic chemicals**.

In the wild crayfish could be expected to survive the occasional short pulses of acidic water that can occur in runoff from upland areas, but not in watercourses with persistently low pH.

Although most populations of crayfish occur in water bodies that are base-rich, some occur in water with lower base-status. Crayfish may be able to acquire sufficient calcium from their food, for example from leaf litter or animal prey (Jay & Holdich, 1981). White-clawed crayfish cannot harden their exoskeletons after moulting if the calcium concentration is below 2.8 mg l^{-1} Ca. The gills increasing absorb calcium at higher concentrations up to 16 mg l^{-1}, beyond which it is not a limiting factor (Foster (1995).

Among the pollutants that can affect white-clawed crayfish are:

- permethrin-based sheep dips, one of the commonest forms of pollution in watercourses that are otherwise highly favourable for white-clawed crayfish in the upper reaches of catchments;
- ammonia from farm slurries and waste water treatment works;
- minewater discharges, containing iron-rich sediments (ochre), often with other metals present and sometimes highly acidic;
- oils and fuels, from spillages, road runoff, boats;
- leachates from landfill or other industrial sites, including contaminated sediments.

At least some crayfish may survive a pollution incident if the pollutant passes downstream rapidly as a plume, such that some parts of the channel are not affected, or get a lower dose. Some crayfish will climb out of the water to escape poor water quality.

In general, white-clawed crayfish populations occur in water of Very Good and Good Quality, (Grades A and B), as assessed by the chemical General Quality Assessment (GQA) scheme used by the Environment Agency. Such waters are characteristically high in dissolved oxygen and low in organic pollution, with low Biochemical Oxygen Demand (BOD) and ammonia. Table 3.1 shows the chemical grading for rivers.

Table 3.1 River Water Quality criteria for chemical grading of rivers and canals (source: Environment Agency)

Water Quality	Grade	Dissolved Oxygen (% saturation) 10 percentile	BOD (ATU[1]) (mg l^{-1}) 90 percentile	Ammonia (mg N l^{-1}) 90 percentile
Very good	A	80	2.5	0.25
Good	B	70	4	0.6
Fairly good	C	60	6	1.3
Fair	D	50	8	2.5
Poor	E	20	15	9.0
Bad	F[2]	<20		

ATU[1] as expressed by adding allyl thio-urea
F[2] quality which does not meet the requirements of Grade E

In the biological water quality assessment of the GQA, white-clawed crayfish are assigned a score of 8 (on the scale from 1-10), reflecting their requirement for water of good quality.

Most sites where white-clawed crayfish are recorded have water quality of grade A or B. Nonetheless, in a survey of 830 sites in Northern Ireland, 14% of the sites that had white-clawed crayfish had a biological grade of C (AERC, 1998). None were recorded in waters with a biological grade of D. Hence white-clawed crayfish can live in conditions that are at least slightly enriched, or have mild organic pollution.

3.5 Freedom from competition by alien crayfish

A white-clawed crayfish population may be threatened by an expanding population of signal crayfish. There is a growing number of studies that demonstrate the ability of signal crayfish to spread in rivers in Britain, (e.g. Guan & Wiles 1996, Peay & Rogers, 1999). Where signal crayfish move into an area occupied by white-clawed crayfish, there may be initial co-existence, but there is gradual replacement of the white-clawed crayfish population by signal crayfish in rivers and in lakes (Holdich & Domaniewski, 1995). Peay & Rogers (1999) estimated 4-5 years from detection of a mixed population to loss of white-clawed crayfish. The time from first colonisation may be much longer, depending on how many years of population growth occur before the invading population can be detected in surveys.

Currently, there are no effective methods of preventing the spread of signal crayfish within a catchment once they have spread into a watercourse. Trapping and manual removal have been demonstrated to be ineffective.

The consequence is that once signal crayfish are loose in a river catchment, indications are that the population will spread progressively downstream and upstream, although the rates may differ. Only a major barrier might delay or prevent the spread of the alien population. As yet, there are no case studies available that show any long-term effectiveness of in-channel barriers.

The two species appear to be unable to co-exist and over time the signal crayfish out-compete the white-clawed crayfish. Several factors are thought to be operating:

- Competition for refuges - signal crayfish are more aggressive and grow larger, so can obtain the best refuges.
- Reproductive interference – large male signal crayfish mate most of the females of both species, but interspecific matings are sterile.
- Other factors – predation; higher fecundity of signal crayfish, plus earlier production of juveniles and faster growth rate.

3.6 Freedom from disease carried by alien crayfish

Signal crayfish may carry the crayfish plague (*Aphanomyces astaci*), a disease which usually has little or no effect on signal crayfish, but is lethal to white-clawed crayfish and other European species of freshwater crayfish. Spores can be carried in water. The life-cycle of the disease is described in detail in Söderhall & Cerenius, 1999.

Plague spores can be carried on angling gear, or with fish used for stocking. Introduction of crayfish plague to waterbodies with white-clawed crayfish populations, leads to large scale mortality, (e.g. Matthews & Reynolds 1992; River Ribble, Lancashire in 2000, P. Bradley, Sheffield University, pers. comm.). Spores of crayfish plague can survive only up to about 16 days in the absence of a susceptible host (Oidtman, 2000). The fungal disease disappears once the white-clawed crayfish population dies. Re-stocking is therefore possible, provided there are no further sources of infection. Persistent re-infection may occur if there is a continuous low level of immigration of white-clawed crayfish from neighbouring areas.

3.7 Key Points on requirements for white-clawed crayfish

- **The principal needs of white-clawed crayfish are:**
    1. **suitable habitat – especially refuges;**
    2. **good water quality;**
    3. **protection from crayfish plague, and**
    4. **isolation from alien crayfish.**

- **If there is limited habitat availability a white-clawed population may be present only at low density, or absent.**
- **Populations need relatively good water quality. If a pollution incident occurs, they may be able to recover over time, depending on the severity of the event and the proximity of an unaffected population.**
- **If crayfish plague occurs, there is rapid mortality in any population of white-clawed crayfish and effects may be extensive. Recovery may be possible by recolonisation from a semi-isolated population locally, or re-stocking of white-clawed crayfish.**
- **If signal crayfish spread into an area occupied by white-clawed crayfish, the native population will become extinct after a few years. There is no known method of restoring a native population in these conditions.**

4. Characteristics of Crayfish Refuges

As shown in section 3.1, refuges for white-clawed crayfish need to be:

- submerged;
- big enough for the size of crayfish;
- stable;
- aerated and in suitable condition, and
- available for use.

Examples of crayfish habitat are showing in the illustrations 1-12. Refuges are discussed in more detail in the following section.

4.1 Submerged features

Physiological studies undertaken by Taylor & Wheatly (1981) showed white-clawed crayfish can survive for up to about 48 hours out of water in humid conditions without experiencing lasting physiological change (permanent damage), but die in 3-6 days. When watercourses are drained for engineering works, some crayfish crawl out of their refuges within a short period of time (within 30 minutes), whilst others stay in hiding for several hours, or until after dark.

Not all potential refuges will be covered at all river levels. Refuges in shallow margins are most susceptible to variations in water level. Good refuges in pools or slow, gliding sections of river are least likely to be exposed. Refuges in the margins may be highly favourable in winter and spring, when flows are higher. Some may become less suitable or unusable in summer due to lower water levels, slower flow and associated siltation.

4.2 Size

Refuge size is important. Foster (1993) showed that in watercourses with stone on the bed, crayfish preferred the largest stones they could get under. Few animals were found under stones of less than 15 cm in size. This is supported by surveys in a variety of watercourses in northern England. Pebbles (16-64mm) rarely hide even juvenile crayfish in stony streams. Cobble (65-256mm) is favourable, but mainly the larger material of 150-250mm or more, preferably over sand or gravel. Banks of unstable small cobble deposited in bars in the channel tend to have very few crayfish.

4.3 Stable

Large, heavy materials such as boulders are less likely to be moved in floods than smaller cobbles, and so make better refuges. River banks may be more stable than loose stones on the bed of the channel, except where the bank is actively eroding. Even if a vertical bank is eroding, there may be boulders or roots present, which provide refuges. Slightly undercut banks can provide favourable sites for refuges, including the burrows made by white-clawed crayfish.

4.4 Aerated and in suitable condition

Siltation

A refuge is only suitable while it stays free of material, or the material can be pushed out by the crayfish. Accumulation of soft, loose silt makes refuges unfavourable for crayfish. The fine sediments clog and abrade the gills of crayfish (and other gill-breathing invertebrates). In addition, bacterial decomposition of organic fines can lead to localised de-oxygenation.

Enrichment by organic silt promotes growth of filamentous algae. This in turn traps more silt. It is difficult for adult crayfish to move through dense mats of filamentous algae. In addition, as the algae grows and dies off, so breakdown of the material leads to more silt and further clogging of cobble and boulder refuges.

There is no clear boundary between water quality and physical habitat requirements with respect to siltation. Input of nutrients, especially nitrates and phosphates, causes enrichment of rivers and other waterbodies. This promotes the growth of algae and other plants, which can be beneficial as a food source for crayfish (plant material and other invertebrates). It also increases organic fines. This reduces oxygen, clogs refuges and blankets the surface of plants, reducing photosynthesis. Inorganic fertilisers in drainage, runoff of organic manures and licensed discharges from sewage works all increase nutrient loadings. Soils from bankside erosion or runoff from surrounding land also contribute to nutrient enrichment. Fine inorganic material, such as clay, silt or sand, may also fill up refuges used by crayfish.

4.5 Available for occupation

"Available for occupation" relates to several factors: condition (mentioned above), accessibility (related to condition) and competition.

Accessibility and burrowing

Crayfish need a refuge with a space big enough to use. They often improve access by burrowing underneath stones or into gaps between them. This is only possible where the substate is suitable for burrowing. In fast-flowing lengths of streams with stony beds, the finer particles, mainly sand and gravels tend to move into the interstices between larger material and to become close-packed. The bed becomes "armoured", especially in the mid channel. It can become too hard for any burrowing. Crayfish occur at much lower density in fast-flowing or turbulent water than in slow-flowing glides, pools and the margins.

Crayfish can live in areas with clay, provided the substrate is reasonably consolidated.

White-clawed crayfish burrow, albeit less than signal crayfish in the same habitat. White-clawed crayfish burrows have now been recorded in a number of watercourses in England (e.g. River Derwent, North Yorkshire; River Witham, Lincolnshire; River Eden tributaries, Cumbria). The opening of a burrow of a white-clawed crayfish is typically 2-6cm wide and wider than high. Use by white-clawed crayfish has been confirmed by survey at night and by excavation.

Signal crayfish burrow much deeper and more extensively than white-clawed crayfish do. The greater number of burrows seen in rivers with signal crayfish is likely to be at least partly due to the signal crayfish being able to reach higher densities of population in slow-flowing lowland rivers (Guan, 1994).

Effects of Competition

There is competition between individual crayfish for the most favourable refuges – those which are:

- big enough,
- stable,
- in an area with not too fast flow, and
- with easy foraging nearby.

Where there is a shortage of very favourable refuges, a larger animal will oust a smaller one from a refuge big enough to accommodate either of them. The size of the chelae is a key factor in determining the outcome. Similar behaviour occurs in white-clawed crayfish and in other species of freshwater crayfish (Gherardi, 2002).

Juvenile crayfish, or adults unable to claim the most favourable refuges make do with less favourable ones, such as smaller stones, shallow margins and filamentous algae or other aquatic plants.

4.6 Other habitat features

Flow

White-clawed crayfish were assumed to prefer riffles. This is probably because:

- routine biological monitoring of streams is based on communities of riffles;
- in chalk, gravel and some other streams, riffles may have the only substrate which can be readily searched for crayfish.

In stony streams the riffles and step cascades are often steep and the flow too energetic for crayfish. Studies of microhabitat use in such streams have shown crayfish prefer slow-flowing glides and pools. Provided they are not too silted with fine sediment, pools offer slow flow, greater depth and so less risk of predation from birds, plus less variation in wetted area of the channel bed.

Other Features

There may be woody debris in pools, which can provide refuges. Woody debris also traps other detritus, especially packs of leaf litter, an important food source for crayfish. Where the water has moderate or low base-richness, leaf litter from trees can provide a source of calcium and other salts.

Tree roots in banks can provide refuges. Juveniles often use the fine roots of alder, provided they are submerged. Juveniles are most commonly found in the margins, rather than in deeper water. In addition to the issue of predation by adults, the shallow margins warm up more in the growing season, allowing juveniles to put on faster growth. Growth increases with temperature, at least into the range 20-25^{o}C (Firkins & Holdich, 1993)

Table 4.1 summarises habitat features important for crayfish. For refuges it is the location and structure which is important, rather than the material. Crayfish will use a wide range of artificial materials for refuges as well as natural ones. For example, they do not appear to discriminate between natural boulders and lumps of old concrete and brick rubble.

4.7 Key Points on Crayfish Refuges

- **Refuges, or shelters are important for crayfish and may be a limiting factor.**
- **Crayfish are not evenly distributed in a stream, or even in an enclosed waterbody. The variety of micro-habitat is very important to the distribution of crayfish at a site. Different areas may be used for shelter, feeding, during the breeding season, or by animals of different size or gender.**
- **Provided water quality is adequate, crayfish can live in a wide variety of aquatic habitats.**
- **Where there is an abundance of favourable habitat, there will generally be a larger population of crayfish than in areas with little useable habitat, unless there is another factor restricting the population, such as pollution.**
- **Some types of habitat are difficult to survey, so crayfish may be present, but at low density, even in areas with little suitable habitat.**

Table 4.1 Habitat Features for White-clawed Crayfish

Favourable	Unfavourable
Water quality • High pH (preferably 6.8-8.6). • Base-rich/alkaline (usually >5ppm Ca). • Well aerated, dissolved oxygen >60% saturated (90 percentile), usually higher. • Unpolluted or largely so; may be slight nutrient enrichment from organic pollution (Grade A to C only).	**Water quality** • low pH <pH6.0, base-poor, low alkalinity. • subject to acid pulses from moorland runoff. • Dissolved oxygen <60% saturated (90 percentile). • Ochreous drainage from peatland drainage or minewater. • Brackish or saline conditions. • Pollution from sheepdips or other polluting discharges.
Flow • Slow-flowing glides (including canals). • Sheltered parts of riffles, • Slack margins, pools, on-stream ponds. • Still waterbodies (lakes, old mineral workings).	**Flow** • Falls and cascades. • Fast riffles. • Flumes (e.g. in culverts). • Other strong currents.
Habitat – substrate • Boulders and large cobble, especially if relatively flat, with cavities beneath. • Cobble and boulder riffles in chalk or gravel streams. • Brick and other rubble in streams and still waterbodies. • Submerged, un-mortared stone revetting which protects banks from erosion; facing walls or rip-rap stone reinforcement. • Small stone weirs/flow deflectors. • Crevices in old or damaged, submerged brickwork, stonework, cracked concrete, or old wooden structures. • Undercut earth banks or steep to vertical submerged banks.	**Habitat – substrate** • Bare sand, gravel, pebble or unfissured bedrock (unfavourable for refuges, but may be used during foraging for food, mates etc.) • Uniform clay channels. • Pebble or cobble shingle regularly exposed by changing river levels. • Gabion baskets filled with pebble-sized stone (<6cm), for bank reinforcement. • Areas of armoured bed where the substrate is compacted by the flow. • Soft silt, especially loosely settled organic fines. • Steel sheet-piling or concrete walls for bank reinforcement. • Sloping banks without any vertical or undercut areas below water level.
Habitat – plant material • Submerged tree roots. • Overhanging trees or branches. • Debris dams. • Leaf packs. • Stands of submerged aquatic plants (if not too dense), e.g. aquatic mosses, water crowfoot. • Bank reinforcement by faggots (bundles of small woody material), or woven willow (like basket-weave, but may be growing).	**Habitat – plant material** • Dense, filamentous algae. • Regularly exposed marginal vegetation. • Dense, silted up stands of emergent vegetation leading to loss of open water.

5. Where White-clawed Crayfish Habitat Occurs

White-clawed crayfish are widely distributed in England and Wales. They occur in many different habitats. This section covers the characteristics of a series of broad habitat types.

5.1 Broad Habitat Types

Different types of habitat typically possesses advantages and disadvantages to resident crayfish populations. The exact nature of disadvantages, or threats, to crayfish populations varies from site to site. Figure 5.1 shows the broad habitat types and provides a key to the tables.

Figure 5.1 White-clawed Crayfish Habitats

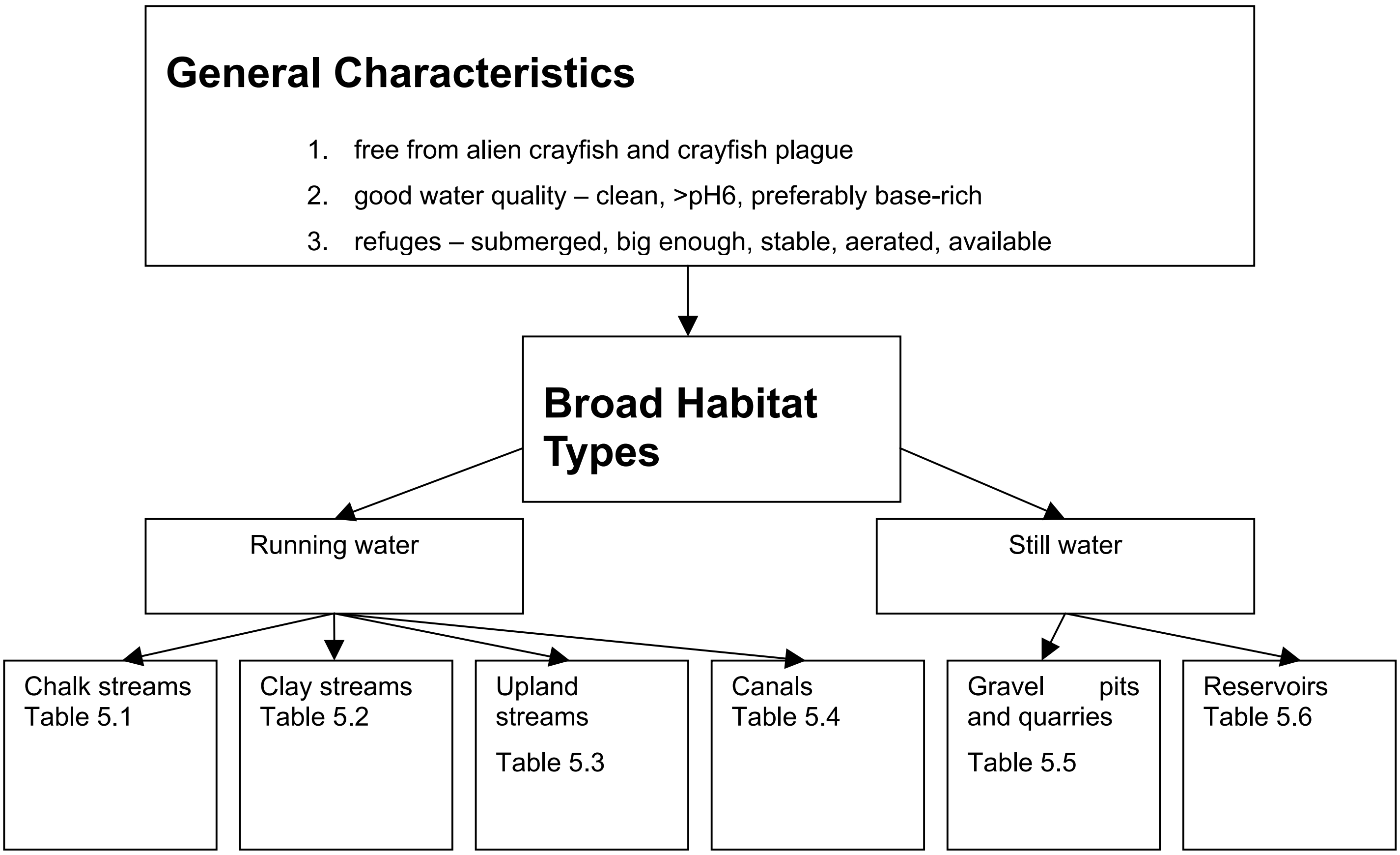


Table 5.1-5.6 show the broad habitat types where white-clawed crayfish occur in Britain. General requirements of crayfish habitat are covered in section 4.1.

The main threats to white-clawed crayfish, wherever they occur, are:

- alien crayfish and crayfish plague
- poor water quality/pollution
- loss of habitat, mainly due to works such as drainage and flood defence
- siltation
- changes in water level/drying out

Only characteristics particularly associated with the broad habitat type are noted in the "Advantages" section of the tables. All habitat types are potentially vulnerable to the same "Disadvantages" or threats, but specific points relevant to the habitat types are noted in the tables. Some types may have potential for introductions of native crayfish in catchments where they are under threat. The protocol for reintroduction of white-clawed crayfish gives guidance on how to appraise the suitability of sites for (re)introduction projects and details on carrying out the work (Scott Wilson, 2002).

Table 5.1 Chalk rivers as habitats for crayfish

Issue in Chalk Streams	**Advantages**	**Disadvantages**
Alien crayfish		Chalk prevalent in southern England where signal crayfish are widespread. Few, if any, catchments free of aliens. High risk of invasion or transfer of plague to remaining native populations.
Water quality	High pH, high calcium, very favourable	Often get nutrient enrichment from agriculture and WWTW. Leads to increasing algae and siltation. This is not always a disadvantage for crayfish.
Habitat quality	Where large cobble or boulders occur this is excellent habitat. Old weirs are also good. But where there is chalk gravel or finer material, have few refuges, except banks and aquatic plants.	Abstraction of groundwater may lead to low baseflow. In low flows can get more siltation clogging refuges. Perennial part of stream may move further downstream. Lower reaches may be dredged and widened for flood defence/drainage.
General suitability	**Can provide optimal crayfish habitat when unmodified, where there are sufficient refuges.**	

Table 5.2 Clay rivers as habitats for crayfish

Issue in Clay Streams	Advantages	Disadvantages
Alien crayfish		River are often part of large catchments – most with signal crayfish, especially in central England. May still have small catchments to sea that are free of aliens. Alien crayfish readily colonise clay banks and attain very large populations.
Water quality	pH usually suitable and base status either base-rich, or acceptable.	Mainly in lowlands so often high inputs nutrients from agriculture, WWTW, and pollution risk from urban runoff. May have high suspended solids and siltation where have bank erosion or discharges entering.
Habitat quality	Banks likely to be good for burrowing, especially where trees roots. Often have abundant aquatic plants, emergent and sometimes submerged.	Mostly modified for drainage/flood defence. May be straightened and lacking in in-channel variation, especially in lower reaches.
General suitability	**Unlikely to provide optimal habitat due to lack of refuges, excessive siltation, or, in some cases, poor water quality. But can have widespread populations of crayfish at relatively low density, or localised.**	

Table 5.3 Upland streams as habitats for crayfish

Issue in Upland Streams	Advantages	Disadvantages
Alien crayfish	Fewer populations of signal crayfish in northern England. Most catchments of Yorkshire region already have aliens, but Cumbria thought to be clear and parts of Northumbria. Peat moorland at watersheds between catchments may provide a barrier to overland colonisation between catchments.	
Water quality	Usually good quality in upland headwaters. A number of catchments in northern England have headwaters on limestone, very favourable.	pH and calcium levels may be too low in some catchments, especially where there is peat. Local risk of pollution from sheep dip.
Habitat quality	Usually lots of in-channel cobble and boulder for refuges. Lots of variation in flow characteristics. Channel more likely to be unmodified and retain e.g. pools/riffles. Traditional stone revetting can provide bankside refuges.	May be a lack of bank-side trees for shelter and leaf-litter. Streams have naturally highly variable flow. Areas of channel with fast flow may be unsuitable, with crayfish highly localised in channel. Floods can cause local impacts on populations.
General suitability	**Limestone catchments can provide very favourable habitat and lead to abundant populations. Other catchments may be poor due to acidity. If not too acid, can have widespread populations, albeit moderate density, mainly in middle or lower reaches.**	

Table 5.4 Canals as habitats for crayfish

Issue in Canals	Advantages	Disadvantages
Alien crayfish	Short canal with independent water supply may be relatively isolated and less likely to be colonised.	Inter-catchment connections mean very high risk of spread of signal crayfish in canal system. Also risk of crayfish plague being carried in canal water and on angling gear.
Water quality	Conditions of pH normally suitable and calcium adequate.	Water quality may be good, but some sections unfavourable, especially in urban areas. May have contaminated sediments in former industrial areas. If the canal is used for navigation, tend to get some diesel pollution, stirring up of silt and loss of aquatic plants due to turbidity; depends on level of traffic.
Habitat quality	Unpointed washwalls/other masonry can provide good refuges, also old lock gates. Slow flow and water level maintained. Not usually subject to flood flows.	Essential engineering work can cause loss of favourable habitat, e.g. dredging, re-pointing masonry, facing banks with sheet piling. Also temporary losses when pounds are drained.
General suitability	**Can provide favourable habitat with abundant refuges. May be problems with siltation. Also loss of habitat to canal restoration/maintenance.**	

Table 5.5 Gravel pits and other former mineral workings as habitats for crayfish

Issue in Gravel Pits and Quarries	Advantages	Disadvantages
Alien crayfish	Population may be relatively protected from alien invasion if waterbody is isolated from watercourses. If site is satisfactorily isolated, native crayfish may have been/need to be introduced.	Risk of transfer of plague where angling occurs and little chance of any recovery by natural recolonisation. If gravel pits are in flood plain, aliens may get in during floods, or over land. Also at risk are any other on-stream lakes or waterbodies close to watercourses.
Water quality	Calcium and pH are often favourable, especially in old marl pits.	Nutrient enrichment from agricultural drainage or pollution from urban runoff may be a problem, but less so than for streams usually.
Habitat quality	Varied bank profiles, rubble infill, rip-rap stone bank protection or even urban rubbish can provide refuges. Fallen branches and leaf-litter may be favourable in old stone-quarries.	Gravel/sand substrate may not provide enough refuges.
General suitability	**Can provide favourable habitat if refuges are available, with lower than average threats from alien invasion. May make good sites for introductions/rescues from populations threatened with invasion from aliens, or displaced by habitat loss.**	

Table 5.6 Reservoirs as habitats for crayfish

Issue in Reservoirs	Advantages	Disadvantages
Alien crayfish	Concrete dam, plus bell-mouth spillway may be sufficient to prevent colonisation by signal crayfish.	Normally onstream, so there is risk of colonisation by aliens along watercourse. Wet spillway is not a barrier. If angling occurs, plague on gear is still a risk.
Water quality	Usually good quality.	Calcium and pH may not be suitable, especially in peat moorland catchments.
Habitat quality	Depending on design, bank protection, e.g. unmortared walls, rip-rap stone may provide refuges.	Drawdown of reservoir may lead to seasonal loss of refuges on the upper bed/banks.
General suitability	**Can provide favourable habitat, if water chemistry is suitable. Sites suitable for crayfish are still at risk of invasion, but some have isolation and could be suitable for introductions.**	

5.2 Key Points on Crayfish Habitat Types

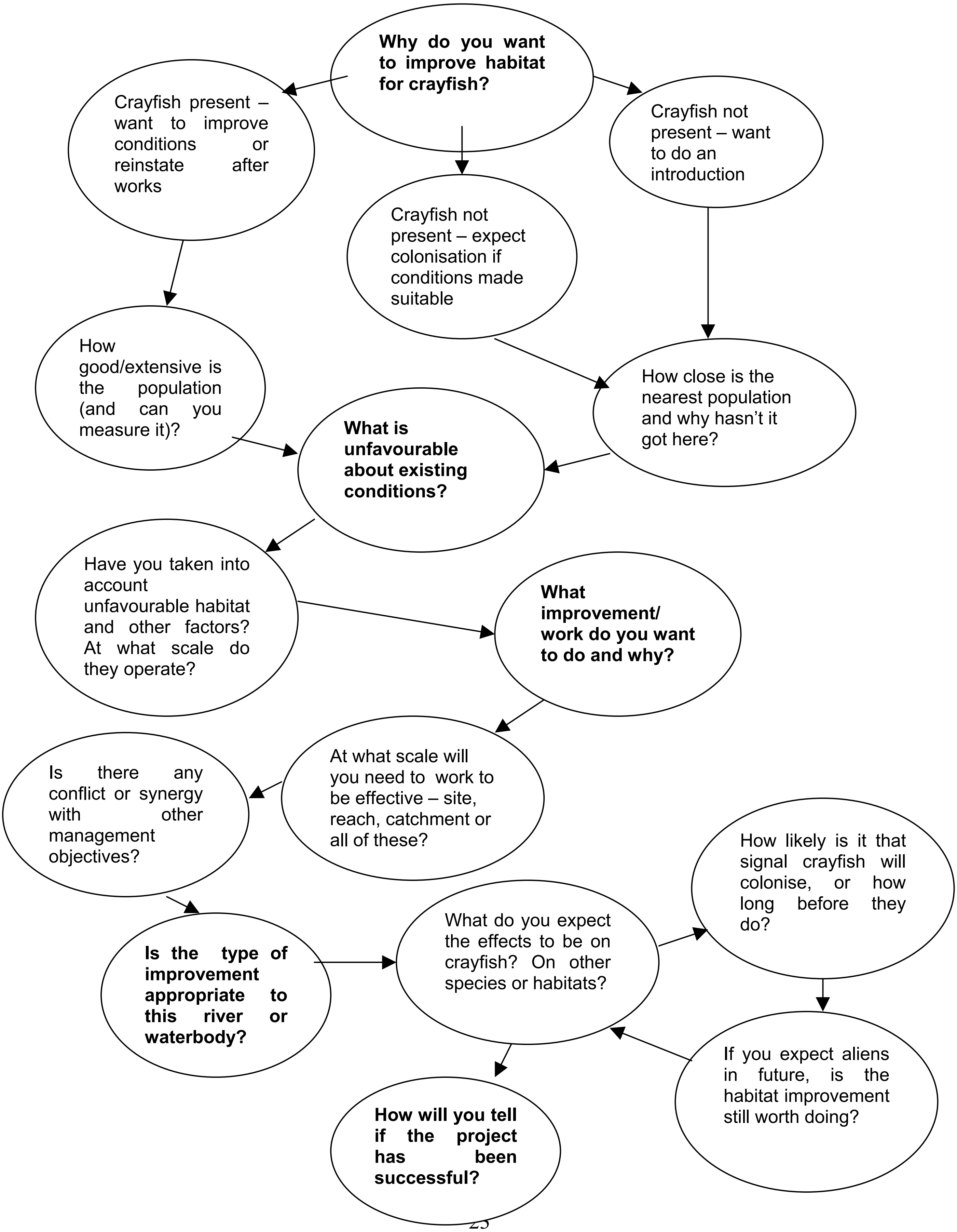
- **White-clawed crayfish are found in a wide range of habitat types; chalk rivers; clay rivers; upland streams (especially on limestone); canals; gravel pits and quarries (and other enclosed waterbodies, and reservoirs).**
- **There are advantages and disadvantages for crayfish in all of these habitats. There is no single ideal set of conditions. The same major threats to white-clawed crayfish can occur in any of these habitats.**
- **The big issues are:**
  - **Alien crayfish and crayfish plague;**
  - **Water quality**
  - **Habitat quality, especially the availability of refuges.**

6. Assessing the Scope for Improving Habitat

It is worthwhile considering the current conditions and objectives carefully before launching into a project on habitat restoration or improvement. Some basic questions are set out in Figure 6.1. Key questions in planning a restoration project are:

- Why do you want to improve habitat for crayfish?
- What is unfavourable about existing conditions?
- What improvement work do you want to do?
- Is the improvement appropriate to this river or waterbody?
- How will you tell if the project has been successful?

Figure 6.1 Crayfish Habitat Restoration – questions to ask before you start



6.1 Why do you want to improve habitat for crayfish?

This question will depend on whether crayfish are present in the catchment and in the reach or waterbody already. If crayfish are already present in the catchment, the aim may be to increase locally or extend the range of the population. In some cases this may involve removal of a barrier to natural colonisation, whether this is a man-made physical barrier or unfavourable conditions.

Another reason for improving habitat is prior to carrying out an introduction of white-clawed crayfish. This may be in compensation for habitat damaged or lost during river engineering or other development work. Alternatively, it may be to establish a refuge population in an area that is as isolated as it can be from any population of alien crayfish.

6.2 What is unfavourable about existing conditions?

Determining what is unfavourable will involve an appraisal of the study area, based on the requirements for crayfish outlined in sections 3-5. A key issue is choosing the appropriate scale. Consider catchment level first and work down to site-specific level.

Catchment Issues -Pollution

If there is a sheep dip pollution incident annually, or every few years in a watercourse, it is better to target individual farms to improve pollution control than start on in-channel habitat creation for crayfish.

If phosphate levels are rising in the stream, there is often a large increase in filamentous algae at the expense of other submerged aquatic plants. Riffles or constructed habitats may silt up very quickly. What are the sources of phosphates? Is it runoff of farm slurry from fields, farmyards or roads? Is it inorganic fertiliser applied to fields? Is it a small waste water treatment works (sewage works), or a lot of septic tank soakaways?

Are there intermittent pollution problems – periodic pulses of water of poor quality – and why are these occurring? Are there acidic surges from minewater discharges or peatland areas? Urban runoff can bring in silt and pollution – salt from roads, oil, storm sewer overflows. How bad and how frequent are these events?

Catchment Issues - Siltation

If there is a lot of silt or other sediment being deposited, where is it coming from? Is it due to natural processes alone, or are there land management factors operating? Drainage associated with afforestation may bring in more water, or more rapid increases in flow following rainfall. Increased runoff occurs from urbanisation too, unless measures are designed in to prevent this.

There may be erosion of earth from banks or surrounding land during or after dredging work, flood defence works, construction of outfalls, or construction work on adjacent land. Runoff from construction sites can be prevented or minimised by good construction practices. Straightening of a section of watercourse, or improvement of flood defences may lead to changes in erosion patterns downstream.

Loss of bankside and aquatic vegetation due to grazing and erosion due to trampling by livestock is a very common source of siltation in streams and rivers. Farm tracks or other routes used by livestock can become muddy, leading to runoff along roads and drainage of mud-laiden water to watercourses. Compaction on arable land can also increase runoff of soil, directly to watercourses, or via erosion gullies in fields to roads.

Catchment Issues – Low Flows

Are there seasonal problems of poor water quality, e.g. during low flows in summer? Are the low flows natural? Watercourses fed from chalk or limestone springs can be especially favourable habitats for white-clawed crayfish. Use of groundwater for local or regional water supplies has led to reductions of baseflow in some stream, especially in southern England. If perennial streams become seasonal, they are unsuitable for white-clawed crayfish.

Catchment Issues – Alien Crayfish

If there is already an escaped population of signal crayfish in one or more watercourses in the catchment, it is likely to be only a matter of time before the signal crayfish spread out and colonise all of the main river and tributaries.

Signal crayfish will certainly escape, over time, from any pond, lake or outdoor fish farm, which has any natural inlet, or drainage outlet. Once in a watercourse, only a major barrier to colonisation, such as a grossly polluted reach of river will delay or stop them. A feature that will prevent colonisation by white-clawed crayfish will not necessarily cause more than a delay to a population of signal crayfish.

When an expanding population of signal crayfish invades any population of white-clawed crayfish in watercourses in the catchment, the white-clawed population will be lost.

Habitat improvements for white-clawed crayfish may eventually provide benefits for signal crayfish! That does not necessarily mean habitat restoration or improvement is not worthwhile– there may be other benefits for nature conservation from habitat improvements for crayfish.

6.3 What improvement work do you want to do?

Choice of improvement depends on the nature of the site, reach or catchment and the identification of any problems. Broadly, it will come down to:

- Improve water quality (pollution control in the catchment and locally, if required).
- Reduce siltation (if this is reducing water quality and/or availability of refuges for crayfish).
- Provide additional refuges (if these appear to be limited).

Opportunities for improvement are discussed further in section 7.

6.4 Is the improvement appropriate to this river or waterbody?

This involves several aspects:

- the natural characteristics of the watercourse or waterbody; such as geology, water supply, topography and habitat types;
- whether the improvement complements or conflicts with other management objectives for the river or other waterbody;
- the potential impact on species and habitats of the proposed works.

Taking account of local geography

There is a great diversity of watercourses in Britain. There is a risk of applying a single “ideal” version of habitat in streams. Many stony streams in northern England have relatively steep bed gradients, which leads to the formation of riffles and pools, shingle bars and meanders. Streams running off boulder clay in the Midlands may have naturally incised banks, few or no meanders at local scale, no naturally occurring gravel on the streambed and no riffles – even in the absence of modification for land drainage. Artificially creating atypical features in streams may not provide the benefits expected, or the features may only have a short lifespan.

Interaction with other management objectives

There may be a whole range of management objectives for the river or other water body. Examples are given in Table 6.1 below with notes on how they may affect management for white-clawed crayfish.

Table 6.1 Interaction of improvements for white-clawed crayfish and other management objectives

Purpose	Potential conflict	Potential synergy
Angling	• Crayfish plague can be carried on angling gear. • Many fish farms have alien crayfish – crayfish plague can be transported with stocked fish. • Use of (alien) crayfish as live bait risks introduction of aliens or disease. • Fish can benefit from the shelter of bankside trees, but trees can impeded access for angling.	• Water quality requirements for salmonid and good coarse fisheries are also favourable for crayfish. • Habitat favourable for crayfish is also good for a range of fish fry. • High density populations of alien crayfish lead to reduction of angling amenity in coarse fisheries, especially in enclosed waterbodies – another reason against introduction of alien crayfish.
Agriculture	• Solving pollution problems from farmyards sheepdip or farmed land may require initial investment. • Planting of trees along watercourses may reduce access to land drain outfalls (and may get root growth in the drains) • Fencing river banks reduces area of grazing.	• Pollution control benefits the environment in general and avoids risk of prosecution. The presence of crayfish can be used to demonstrate the recovery of watercourses after pollution. • Trees in the riparian zone can provide shelter/shade for livestock. • Construction of hard-standings for stock-watering, or stock-operated drinkers improves the quality of water for livestock. • Fencing can prevent livestock from being injured in falls from banks. It can help reduce incidence of liver fluke and worms. • Preventing grazing of banks by livestock can reduce loss of farmland to erosion by water and reduce siltation of crayfish habitats. • Measures to prevent runoff of soil from arable land can improve the quality of crops.
Flood defence	• Deepening, straightening and hard-reinforcement of river channels lead to loss of crayfish habitat. • Removal of debris dams leads to loss of refuges and feeding areas for crayfish. • Retaining woody debris or adding structures could change local flooding patterns or cause erosion downstream; although this is not necessarily a problem.	• Set-back of floodbanks away from the river gives opportunities for reinstating more natural channel morphology and improved riparian zones. • Some types of bank reinforcement can provide refuges for crayfish, e.g. unmortared stone-faced banks (stone revetting), or willow spiling.
Navigation	• Sheet piling or concrete walling of banks causes loss of bankside refuges. • Provision of some types of refuges could be a hazard to boats in narrow channels such as canals.	• Dredging of channels and weed-cutting can cause loss of habitat and crayfish, but can prevent canal or other slow channel becoming too clogged with emergent vegetation.

Effects on other species

Consider the implications of habitat improvement on other species. Improvements in water quality will benefit a wide range of habitats and species. Refuges of benefit for white-clawed crayfish may also benefit species such as the fish species bullhead (another Biodiversity Action Plan species) and stone loach. Planting of trees may improve bankside refuges for crayfish. It may also benefit fish fry, or make the stream more attractive to otters.

Are there any potential adverse impacts? Introduction of white-clawed crayfish to a new area might have an adverse impact on a population of a rare submerged aquatic plant, if the species happens to be palatable to grazing by crayfish. Will any change in the channel reduce the availability of emergent plants for water vole? Will installing a new riffle lead to the loss of a shingle bar of importance for specialist invertebrate communities of exposed river sediments?

Erosion of earth banks due to trampling by cattle or sheep may be undesirable, but erosion of steep, sandy outcrops by a river may provide important breeding sites for sand martins, or for some species of burrowing bees and wasps. Will natural erosion by the river keep sand cliffs open if the banks are fenced against grazing, or not? Accumulations of organic silt in the margins may not be favourable for crayfish refuges, but unpolluted silt provides habitat for the larvae of the brook and river lampreys, which are also Biodiversity Action Plan species.

6.5 How will you tell if the project has been successful?

Have the project objectives been met? Answering this will require some kind of post-project appraisal. This should be planned at the project planning stage, because the criteria for assessing the success depend on the objectives.

The type of appraisal needs to be planned at the start – will it require one or more surveys? What will you record, how and why? Do you need a baseline survey before you do the project in order to provide a comparison? Are you looking for qualitative change or change you can quantify – and if so, how?

Example of the effect of selecting different objectives

There is concern that in a particular reach of river there is a lot of erosion of the banks, due to grazing and trampling by livestock. A survey for crayfish in riffles next to bridges shows crayfish are present. It is thought that the extensive silty reaches are unfavourable habitat for crayfish. The aim is to improve the reach for white-clawed crayfish. In this example three alternative objectives are considered and their implications. In each case the project proposal (prescription) is to fence the riparian zone along both banks of the river to reduce silted areas of the channel. Table 6.2 shows the options for objectives and the survey requirements before and after the project.

Table 6.2 How choice of objective affects survey/monitoring requirement

Choice of Objective	Survey before and after	Success if:
Option 1 Reduce eroding earthbanks from 90% to 10%.	River Corridor Survey/ mapping of banks in study area, to show location and extent of erosion.	Eroding banks 10% or less after 3 years.
Option 2 Increase extent of favourable habitat for white-clawed crayfish within the channel.	Detailed survey of in-channel habitat graded/assessed for suitability for crayfish – need qualitative scale (use evaluation in standard method, Peay, 2002, plus mapping).	Increase in percentage of channel graded as suitable for crayfish.
Option 3 Increase the population of white-clawed crayfish in study area.	Detailed population study of crayfish, involved detailed assessment of in-channel habitat and semi-quantitative survey of crayfish (standard method, plus additional fixed area sampling and possibly other methods).	In comparable conditions, by same survey methods, record significant increase in population.

In this example, the objectives are increasingly specific; from target changes in habitat, to improvement in the population of the target species. The survey requirements to verify success become more demanding.

The prescription, fencing the banks, is based on the assumption that bank erosion is causing siltation in the channel. It also assumes that siltation is reducing the quality of habitat for crayfish and that habitat availability is the limiting factor for the population.

Objective (1) is easiest and cheapest to appraise as it just deals with the eroding banks. But you cannot be sure whether the successful works actually lead to an increase in the crayfish population, unless the more onerous objective (3) is set and tested.

Objective 3 will cost much more in time and resources. It will not be possible to survey the whole study area in the same degree of detail. It will cover either all the habitats within the channel, or those habitats that can be surveyed.

It is important to consider all the factors that may be affecting the crayfish population. The fencing of the riparian zone may be enormously successful in improving the habitat. It may not result in a greater crayfish population if there is a severe sheep-dip incident, say one year in three.

Even if there is uncertainty over the degree of benefit to white-clawed crayfish, the improvement in the quality of riparian habitat may be sufficient in itself to consider the project a success. In addition, if poor quality habitat is improved, but the crayfish population does not appear to respond, this may be a reason to look for some hitherto undetected problem in the reach or catchment.

6.6 Key Points on Assessing the Scope for Improving Habitat

- **Good planning is essential to a successful project.**
- **Identify all the factors that are operating on a study area to plan what is feasible and appropriate.**
- **Identify conflicts and synergies with other management objectives – they could prevent you undertaking work, or could be the source of support and resources.**
- **Consider the effects of proposals on other aspects of nature conservation – which species and habitats will gain and will any be adversely affected?**
- **Set project objectives carefully and realistically.**
- **Allow time and other resources for any surveys needed before and after the project.**

7. Options for Habitat Restoration or Improvement

The general approach to planning a project to benefit white-clawed crayfish was shown in Figure 6.1. The aim is to identify any threats to the species in the study area, any unfavourable conditions. As identified previously, the main issues are:

- alien crayfish and crayfish plague;
- poor water quality;
- poor habitat or lack of refuges.

Options for tackling these issues are outlined in the following section.

7.1 Alien crayfish and crayfish plague

Alien crayfish

An R&D study was commissioned by the Environment Agency on the scope for eradication of alien crayfish (Scott Wilson, 2001). Findings include the following:

- The spread of signal crayfish and other alien species in rivers cannot be prevented or slowed by trapping, manual removal or predators.
- Weirs, spillways and locks have not been found to prevent the spread of alien crayfish, although they may delay it slightly.
- Signal crayfish can walk overland from ponds to watercourses, 10’s to possibly 100’s metres.
- To be effective, barriers need to be either very substantial or specially designed to prevent crayfish walking or climbing over/through them.

There is little that can be done where alien crayfish are already in the wild. The few measures available to prevent new colonisation are:

- Use of physical barriers – where feasible, may not be possible in rivers.
- Promote awareness of the threat of alien crayfish to native populations and discourage introductions.

Promote awareness of alien crayfish

The introduction of signal crayfish has sometimes been promoted as a method of weed control in angling lakes. Typically, such an introduction eventually leads to the alien crayfish reaching a high population density. This becomes a serious nuisance for coarse angling as the crayfish take angling baits.

Live crayfish were used for angling bait. This has a high potential for introducing alien crayfish or crayfish plague. The Environment Agency has introduced a national bylaw prohibiting the use of crayfish as live bait.

Crayfish plague

Raising awareness of crayfish plague is a key factor. Local angling clubs can encourage their members to take measures to prevent plague, to look out for any crayfish affected by disease (for example out in the open by day or moving abnormally), to inform the Environment Agency of the presence of alien crayfish in any new areas.

There is an information leaflet produce by the Environment Agency on Crayfish Plague, plus the booklet "Freshwater Crayfish in Britain and Ireland" (Environment Agency, 1999).

Actions may include:

- promoting the use of disinfection procedures for angling and canoeing gear;
- In catchments or waterbodies with solely white-clawed crayfish, promoting the use of only locally reared fish for stocking, to prevent the spread of crayfish plague.
- If plague occurs, encourage anglers and others to stay out of the water – large quantities of spores are released from dying crayfish and the water becomes highly infective.

Role of disinfection

Disinfection of gear is by removing mud and debris, then dipping in hypochlorite solution (domestic bleach). Alternatively, an iodophor can be used (100ppm iodine or more). Spores of the crayfish plague require wet or humid conditions. Complete drying also kills the spores.

Use of "plague-free" stocks of fish for sensitive waters

Many fish farms have populations of alien crayfish. There is the potential for the transfer of crayfish plague with the fish used to stock waters which have white-clawed crayfish.

There is no currently approved product for the disinfection of fish against crayfish plague. It is preferable to use fish which have been reared in isolation from other fish stocks for stocking waters which solely have white-clawed crayfish. Fish from catchments with alien crayfish should not be used.

7.2 Water quality

Poor water quality

Figure 7.1 gives examples of sources of poor water quality, the effects of pollutants and approaches to dealing with the problems. The issue of acidity is shown separately in Figure 7.2. Details of treating acidic pollution are beyond the scope of this guidance and will be dealt with by the Environment Agency. The effects of licensed discharges are addressed through the review procedures of the Environment Agency. Diffuse sources of pollution are more difficult to identify and tackle.

Agricultural land management need to be considered at the level of the individual farm and the wider catchment. The Environment Agency has produced guidance (Environment Agency, 2001) on how farmers can identify the problems that can lead to pollution. It emphasises the financial savings and other benefits to farmers of protecting soil and water, with worked examples. The publication includes a list of currently available guidance and codes of practice for farming. It also details sources of advice and grant aid.

Section 7.3 below deals with siltation under habitat quality. Siltation is an issue of both water quality and physical habitat quality.

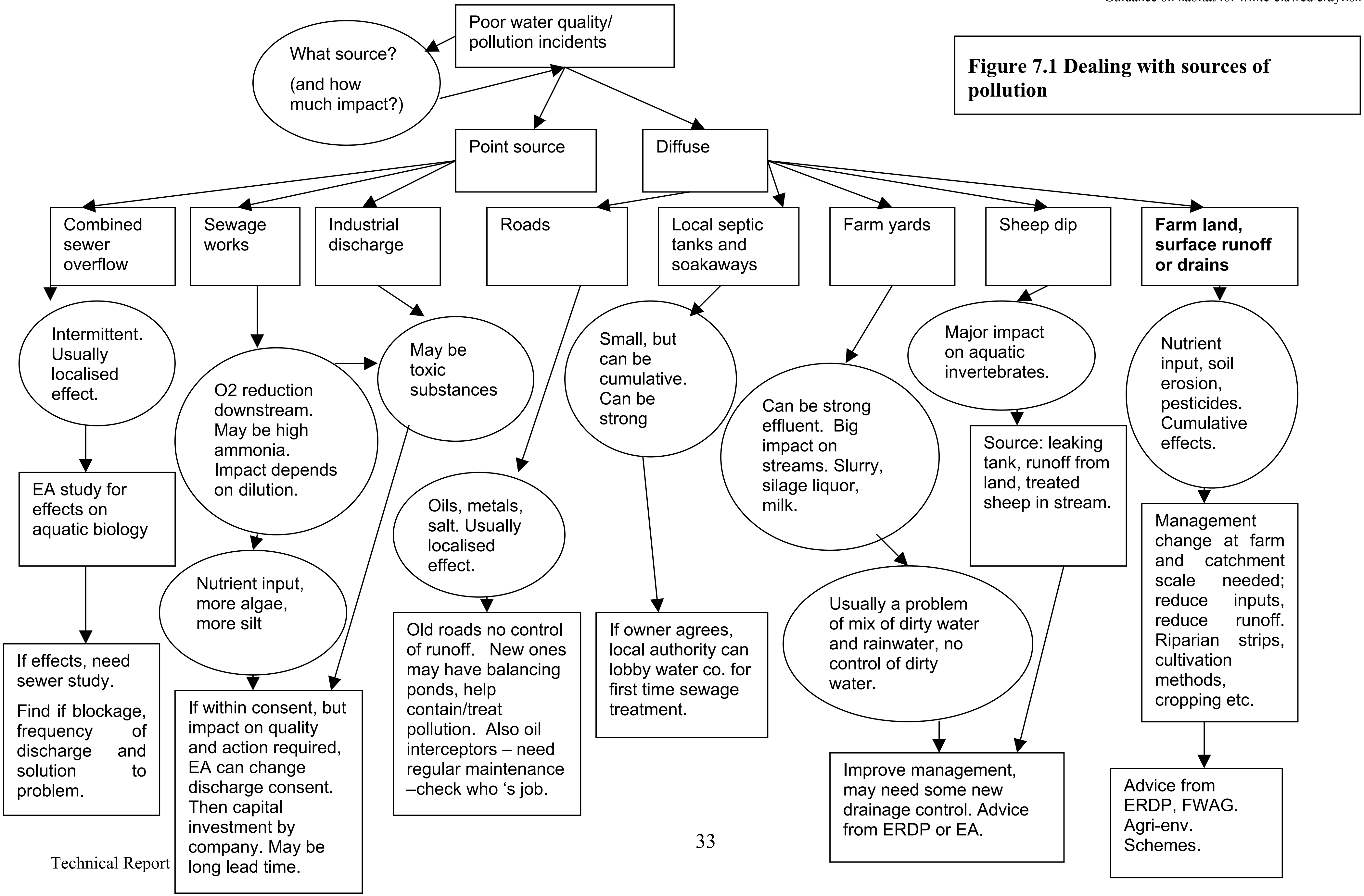
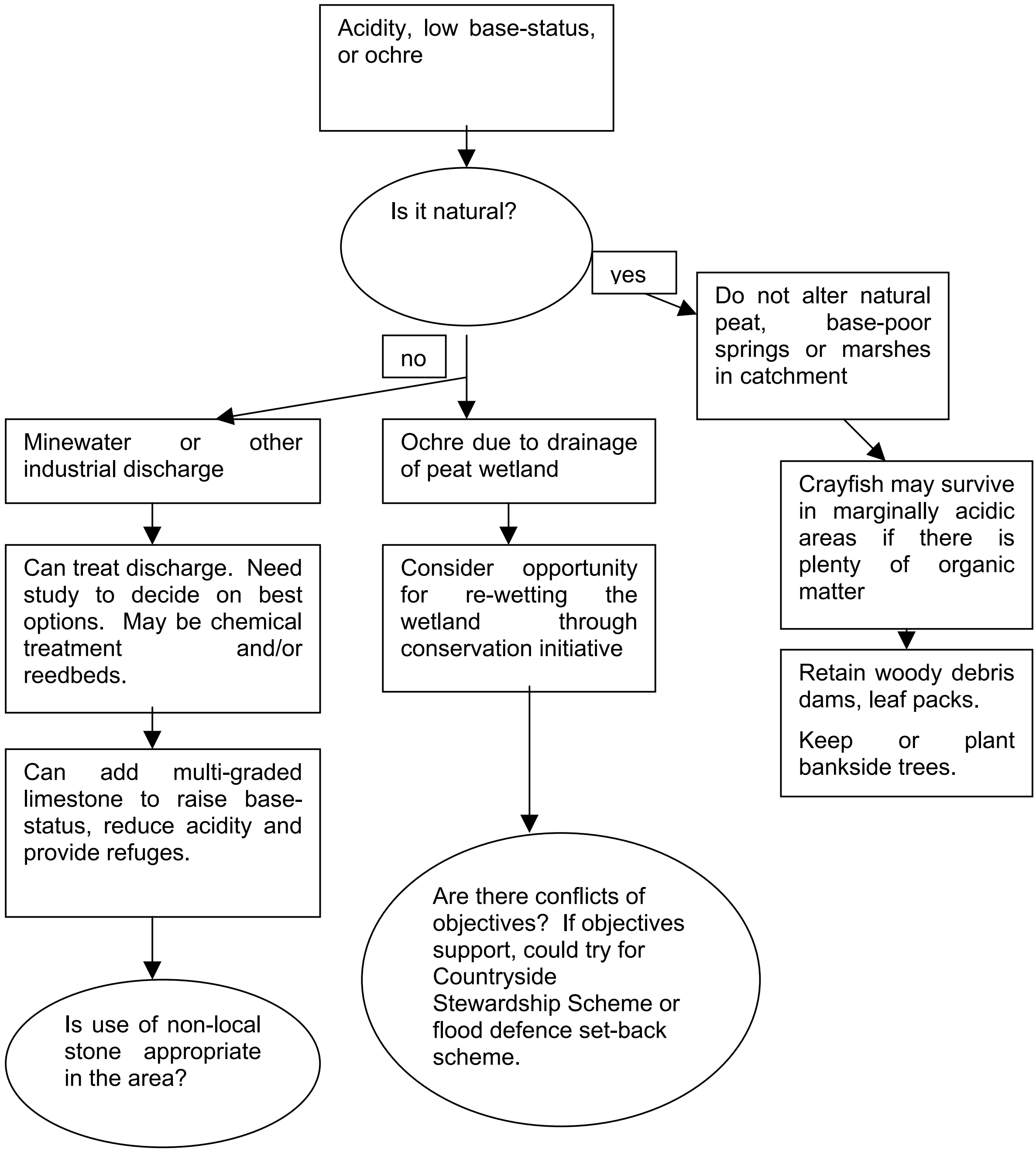


Figure 7.1 Dealing with sources of pollution

Figure 7.2 Options for dealing with acid conditions



7.3 Habitat quality

Siltation

Water courses that have become wider due to engineering works or through and loss of riparian habitat are prone to slower flows can lead to deposition of silt and prevent scouring of the substrate.

The guide on best farming practices (Environment Agency, 2001) includes a wide range of examples of measures that will prevent or reduce runoff of soil to watercourses and runoff of fertiliser and manures. Examples of the recommended measures are summarised in Table 7.1.

Table 7.1 Actions in farming to reduce runoff

Measures to reduce risk of pollution
• Keep clean water separate from 'dirty water'. • Time application and location of manure spreading. • Use organic manure effectively to reduce inorganic fertiliser requirements. • Target inorganic fertiliser to crop needs. • Use a cover crop to reduce leaching of nitrate.
Measures to reduce soil erosion (and pollution too)
Mainly for arable farming • Avoid loss of soil structure (compaction) which can lead to erosion. • Optimise crop establishment to reduce runoff. • Use grass, hedges and trees in buffer strips to reduce the risk of soil erosion and settle sediment before it reaches watercourses or roads. Create river corridor buffer strips (improve riparian zones). • Keep vegetated ditches to trap sediment from runoff and clean them out on a rotational basis, rather than all in one year.
Mainly for livestock farming • Manage livestock to prevent poaching of soils (excessive trampling and puddling). • Manage and surface farm tracks to prevent muddy runoff. • Keep livestock out of farm ditches. • Fence off watercourses, ditches and wetlands to prevent erosion. • Use temporary electric fencing along river banks where flooding may occur and to allow periodic grazing of bankside grassland. • Provide specific stock-watering systems or sites.

Buffer strips next to watercourses

Retaining a thick grass sward or other permanent vegetation next to streams and rivers:

- improves bank stability,
- intercepts runoff,
- prevents livestock from polluting watercourses,
- can reduce the incidence of injury and disease in livestock, and
- provides semi-natural habitat in the riparian zone,
- reduces the channel width.

White-clawed crayfish benefit from improved stability of banks and from having secure refuges in banks, such as among tree roots. The presence of permanent vegetation along the streamside will help to retain those areas of vertical, but relatively stable banks that provide good refuges for crayfish. Reducing damage to the banks means in-channel refuges are less prone to siltation. Interception of soil and fertilisers to streams by buffer strips may help to prevent excessive growth of algae and emergent vegetation. This helps to retain the patchy distribution of aquatic plants and bare substrate most favoured by crayfish. Photographs 13a and b and 14 a and b show the prominent effects on riverside vegetation of fencing the banks.

Flow or water level

Problems of seasonal low flow in watercourses may be due to natural climatic conditions, but can be due to abstraction too. Abstraction of groundwater for water supplies can reduce the flow for groundwater into streams during summer and autumn, an issue in the headwaters of some chalk streams. Where this is suspected, a study of the groundwater and surface water will be needed to assess the effects of the abstraction. In some cases the Environment Agency may negotiate a reduction in the licensed abstraction, or a change in the operation of one or more sources of water.

Land drainage can also lead to the reduction of baseflow in headwater streams, if springs are piped away or wetlands are drained.

Slow flow is not a problem for crayfish, provided it is reasonably clean and not too silted, as they can live in still water. Depending on the stream, however, it may make bankside refuges unusable. Drying up of part of the channel will make conditions unsuitable for white-clawed crayfish.

Large variations in flow are a natural aspect of most types of natural watercourse, so water level varies. Crayfish tend to avoid areas where refuges are subject to frequent inundation and exposure.

Fast flow is a problem if the current is too strong for the crayfish to be able to move in it. If the bed is rough, with a lot of cobble and larger stone, friction will lead to areas of slower moving water among the material on the bed making it more suitable than the same flow over a smooth bed.

Flow deflectors or low artificial weirs speed up the flow in localised areas of the channel. They are sometimes used to provide variation in flow in an over-widened channel. Flow deflectors may provide some areas of unsilted bed in a predominantly silted watercourse. This can improve the in-channel habitat in a modified, uniform watercourse, if it allows the channel to re-scour to a reduced width and lets vegetated margins develop. Depending on the construction, flow deflectors may offer refuges for crayfish, see section below. Even in modified channels, flow deflectors may not be appropriate to the type of watercourse. The characteristics of the watercourse, channel and flows in it should be carefully investigated before introducing flow deflectors. Details of methods are shown in Ward *et al* (1994).

Refuges

The provision of refuges for crayfish can take a variety of forms. Examples given in Table 7.2 include provision of:

- stone on the bed
- stone along the banks
- wood or vegetation along the banks
- artificial refuges

In many reservoirs there is riprap or other stone reinforcement, to reduce bank erosion caused by wave action. It does not necessarily extend down onto the lower banks. Reservoirs for public water supply may be drawn down below the level of the stone at times, leaving a shortage of refuges for white-clawed crayfish. Over time, the bottom of a reservoir tends to silt up. This can cover refuges too. If the reservoir is routinely emptied or drawn down to a silt bed, it is likely to stay as poor quality habitat for crayfish.

Better provision may be possible if a permanent pond is provided near stream inlets to the reservoir. Many reservoirs have silt traps at the inlets, which are cleaned out periodically. Refuges in silt trap ponds will also disappear as silt accumulates, but the sites are designed to allow access for maintenance and they benefit from relatively stable water levels.

Table 7.2 Creating refuges for crayfish

Form of refuge	Technique	Comments
Stone on the bed	• Place large cobbles or boulders (>20cm across) on the bed. Stack to leave gaps for crayfish.	Best in deeper areas not regularly exposed by changing water level. Local stone is best. Is use of stone appropriate to the type of watercourse?
Stone along banks	• Place large cobbles or boulders (>20cm across) in the margins. • Can stabilise eroding slope with unmortared stone. Use unfaced stones or gaps between will not be big enough.	Not useful if banks are mainly exposed, or shallow water adjacent. Does the bank have to be stabilised? Natural bank is preferable – crayfish like vertical banks with projecting stones and tree roots below water level. Gabion baskets filled with small stone, <15cm, don't have gaps big enough for crayfish, except a few juveniles.
	• In highly modified river channel or canal can create new bank. • Drive stakes into bed of channel margin. Backfill with large stone (>20cm). Cover with soil. Can re-seed, turf, plant trees.	In river consider effects on flow, including scour elsewhere. In canal consider navigation. This would be better than gabion baskets with small stone. Could make a good fishing platform in a gravel pit.
Wood or vegetation along banks	• Plant trees along banks for shade.	Trees on vertical, slightly undercut banks are best, with large roots and a pool below. If have too many trees will lose most aquatic vegetation. Tree roots can be a source of leakage on artificially raised rivers, canals or earth dams.
	• If have to stabilise bank can use stakes with branches interwoven (basket-weave spiling). If use fresh-cut willow stakes it will grow. • Can use faggots for facing bank – twiggy coppice stems, hedge cuttings, other woody brashings etc. tied in a bundle, then pegged or staked across the exposed bank.	Willow walls need maintenance – coppicing and/or cut and weave. Faggots need replaced over time. As with stone, is reinforcement necessary? If so, this is a better option for crayfish than solid walls or piling.

Artificial refuges	• Attach short sections of plastic pipe to structures (bridges, walls etc.), use 20—50mm diameter. Can attach plastic mesh or hessian sacking to pipe area and bed to encourage crayfish to climb up to refuges.	Can use these in canals or highly modified rivers, e.g. where essential engineering works cause loss of bankside habitat.
	• Drill holes c. 20-50mm into sheet piling near the channel bed and at various levels above the bed to allow access to bank. Or, leave gaps, c. 50mm between sheets or cut/leave "letter-box" slots, backfill with coarse fill if necessary.	Crayfish will not swim up to holes so must be able to climb. Future siltation may cause bed to cover holes over time, hence need for holes at different levels.
	• Face wall or hard bank with a few layers of brick set on side, with holes facing outward. • Take standard concrete block (breeze-block), place on side. Pack space with sections plastic pipe 20-50mm diameter. Glue in place, or bed into mortar at the back. Set at right angles to flow.	Can use this under bridges and in large culverts. In culverts can use the brick or blocks with cavities to support a dry ledge that can be used by otters or other mammals.
	• Take either coarse hessian sacking or plastic netting (e.g. strawberry net). Fill loosely with straw in a 'pillow' or 'sausage'. Peg bag to bed in submerged margins.	Good for juveniles. Can use in a lake or gravel pit. Using nets with barley straw close to water inlets helps reduce growth of algae, if nets are in place before start of season (February). Needs a top up of straw every year or two. Can make juveniles easier to detect in surveys, if sample the bags.

Plastic domestic plumbing pipes come in standard sizes of 21.5, 32 and 40mm diameter, typically in lengths of 2m or 3m. They can easily be cut into short sections for use in artificial refuges. Their buoyancy means plastic pipes need to be bedded in or attached to structures. Metal pipes could also be cut into short sections and used although corrosion products may make them unsuitable over time.

Additional guidance is given in Peay, (2001) on planning and implementing works in river channels that may affect white-clawed crayfish.

7.4 Key points on options for habitat improvement

- **Isolation of white-clawed crayfish from alien crayfish is essential, but barriers to colonisation by signal crayfish are difficult to achieve.**
- **Obtaining the support of angling clubs will help to avoid the spread of crayfish plague and discourage illegal introduction of alien crayfish.**
- **Pollution can occur from a wide range of sources and effects can be cumulative – mild nutrient enrichment may not harm crayfish, but greater levels of organic pollution may damage populations.**
- **Impacts from agricultural land use are best tackled at the levels of the individual farm and catchment, preventing or reducing polluting runoff.**
- **In-channel modifications and artificial refuges can provide habitat where past modification of the channel has reduced or removed habitat suitable for crayfish.**
- **Refuges can be created on the bed, but banks are also highly suitable places to create habitat for crayfish.**

8. Key Points on Habitat Restoration or Improvement for White-clawed Crayfish

So what work is worth doing, or what are the priorities? Figure 8.1 gives a summary. The key points are:

- **Sorting out pollution problems in the catchment – always worth doing, as there are benefits for aquatic species and habitats and there may be benefits for riparian or other terrestrial habitats too.**
- **Protecting, improving or extending riparian habitat – generally worth doing, wide range of benefit for nature conservation, for range of riparian and aquatic habitats and species.**
- **Modifying or providing new physical habitat features in the channel – sometimes worth doing, if channel is heavily modified and if the new features are definitely characteristic of the watercourse type. Features will not necessarily create suitable microhabitats for crayfish.**
- **Re-instating channel after works – opportunities depend on the type of work, but there may be scope for significant enhancement.**

8.1 Resources

If there is loss of habitat during engineering works on rivers with white-clawed crayfish, the budget for works should include provision for mitigation measures. These should be designed to minimise the adverse impacts of works on crayfish and where semi-natural habitat will lost permanently, compensation measures should be included, wherever practicable, to provide replacement habitat at the site of loss, or elsewhere.

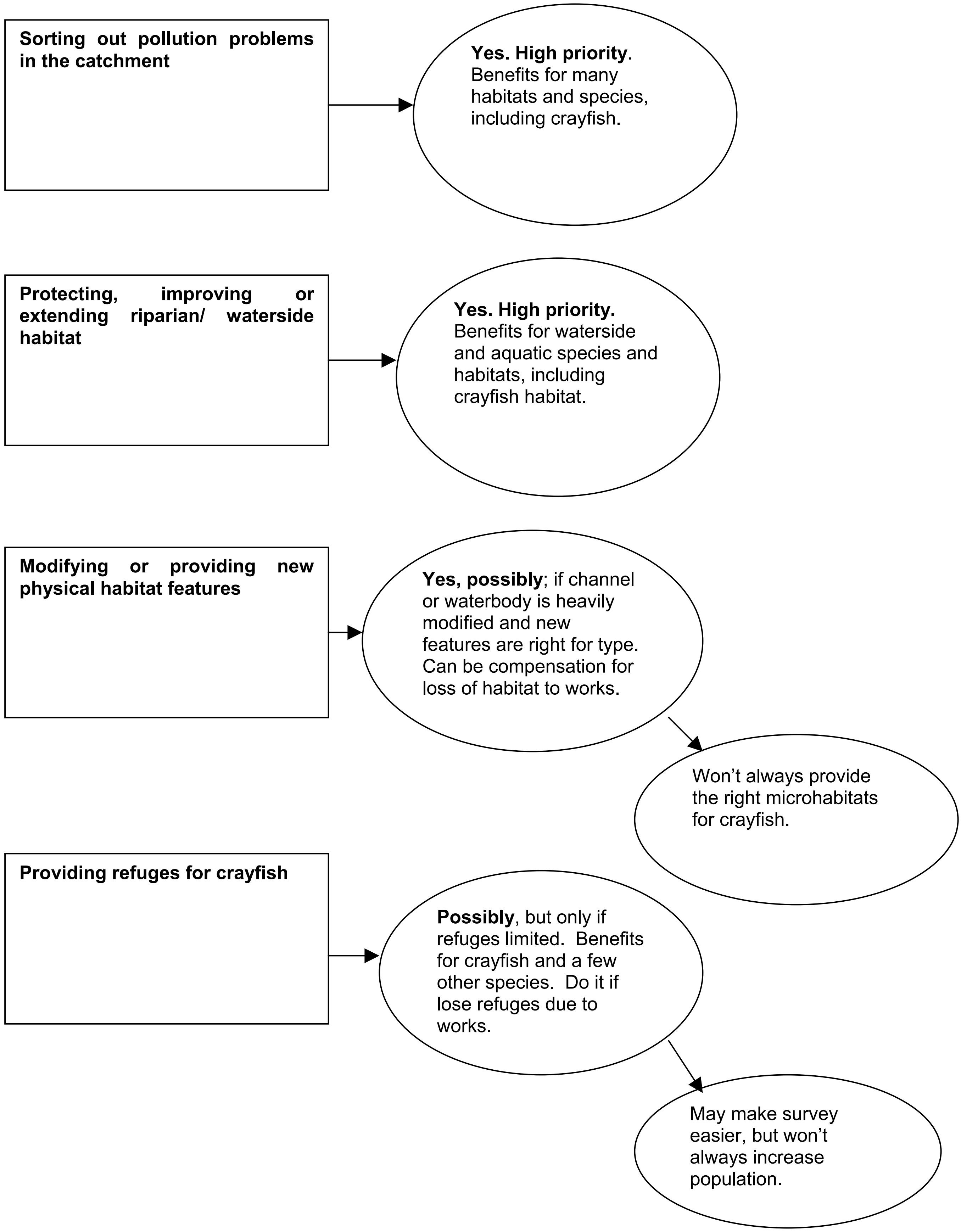
In rural areas, some projects, e.g. riparian buffer strips, may eligible for one of the environment schemes under the England Rural Development Programme of DEFRA. Funding may be available from:

- Countryside Stewardship Scheme
- Environmentally Sensitive Areas
- Woodland Grant Scheme

Note that none of these is intended to aid white-clawed crayfish, or indeed other aquatic species. There are strict eligibility criteria, nonetheless, some of the prescribed work under these schemes can benefit white-clawed crayfish, via better riparian habitat.

Further guidance on white-clawed crayfish is available from staff at regional offices of the Environment Agency and English Nature. They can obtain specialist advice if it is required.

Figure 8.1 Priorities for works to benefit white-clawed crayfish



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APPENDIX 1 CASE STUDIES

These case studies were prepared with the assistance of Erica Kemp, (Scott Wilson, Leeds) and the project coordinators.

Seven projects are outlined here that involved enhancement or creation of habitat for native crayfish, although provision for crayfish was not necessarily the main objective of the individual projects. Some were carried out to provide habitat to replace that lost during essential engineering work. There were sometimes other objectives for nature conservation. The locations of sites are not given in detail, because the sites are generally on private land and some of the project coordinators asked for the locations to remain confidential.

Table 1 summarises the case studies. It shows the threat to native crayfish at each site and the action that was taken to help secure their future.

Table A1 Summaries of case studies

Site	Threats	Treatment
Huddersfield Narrow Canal	Loss of refuges due to engineering works including: • Re-pointing of structures • Bank stabilisation and historic siltation	• Addition of in-channel stone and installation of plastic pipe refuges. • Sheet piling back-filled with rip-rap, with gaps to allow crayfish access to banks. • Dredging to remove accumulated silt and installation of refuges above canal bed to reduce future siltation of refuges.
River Darent	Lack of suitable refuges Siltation	• Construction of dry-stone aquatic ledge along a section of bank, creating refuges of various sizes. • Creation of ledge to narrow the channel, slightly increase flow and reduce sediment deposition.
River Itchen	**Downstream alien crayfish population** Lack of refuges Lack of shading Siltation	• Enhancement features upstream of native population to encourage upstream rather than downstream migration thus maximising time before populations mix. • Importation of chalk flints on to existing suitable substrate to create additional refuges. • Tree and shrub planting on banks to provide shading and an additional food source. • Installation of channel narrowing features (hazel faggots) to quicken the flow and move sediment, revealing gravel and chalk bed. • Installation of semi-permanent fencing to reduce grazing pressure and destruction of new channel features during establishment phase.
Ornamental Pond in Kirklees	Canal population threatened by adjacent signal crayfish Lack of suitable refuges in new site (cement lined pond)	Crayfish translocated to a safe site (ornamental pond), with suitable water quality and no inflow/outflow (to prevent colonisation by alien crayfish). • Stones stacked on pool bed to create variable size refuges prior to translocation of crayfish.
Dowdswell Reservoir	Lack of refuges in summer due to variable water levels. Acidification	Construction of stone groyne to create permanent habitat at high and low water levels. Creation of pools to retain water during low periods. • Enhancement features created from limestone to increase calcium content of water and raise pH.
Long Preston Beck	Active erosion of steep bank	• Construction of stone block reinforcement, providing stable submerged refuges for crayfish in the bank.
River Leith	Loss of refuges in banks and siltation, due to trampling by livestock	• Fencing of lengths of the riparian zone to allow recovery of riverside vegetation and reduce erosion and trampling

Huddersfield Narrow Canal, West Yorkshire.

Coordinated by Nick Birkinshaw, British Waterways

The Huddersfield Narrow Canal forms part of the South Pennine Canal Ring, and has recently been reopened for navigation as part of a socio-economic regeneration scheme for the Huddersfield area. Major engineering works, including bridge replacements, bank stabilisation and dredging works were required to restore the canal to a navigable standard.

Crayfish were discovered in a 6 km stretch of the canal during routine survey work in summer 1998. They comprised the only known population of native crayfish in the Kirklees district at that time.

Further survey was carried out in 1999, prior to the commencement of the restoration works, to assess the status of the crayfish population, facilitate the design of appropriate enhancement and mitigation techniques, and minimise disturbance to crayfish both during and following the restoration. Night-viewing techniques were used to identify favoured habitat niches within the channel. These revealed that most crayfish activity was focused around unpointed masonry (such as wash-walls and bridges) and piles of in-channel stones. These features provided refuges above the sediment of deposited silt in the channel bed, which was up to 1 m thick.

Engineering works required in areas containing native crayfish included:

- replacement of a leaking aqueduct;
- replacement of a bridge;
- bank stabilisation works, including discrete areas of sheet piling;
- general dredging works to remove in-channel debris and accumulated silt, which was present at depths of up to 1 m.

If no mitigation was undertaken these projects would reduce the amount of crayfish habitat through the loss of in-channel stones, unpointed stonework and bank-side refuges.

Works undertaken

Disturbance to crayfish was minimised by ensuring that original habitat features were retained wherever possible. Unpointed wash walls and the natural towpath bank were retained in areas where this would not affect the integrity of the canal. Marginal vegetation was also retained to provide shelter for juveniles and a food source for all crayfish.

Crayfish rescues were carried out prior to dredging works, by draining down the canal to expose the wash-walls and margins. The work was carried out during the winter months, a time when much of the population was relatively inactive and hidden in the wash-walls of the canal. Crayfish emerged in response to lowering of the water level. After repeated drawdown, geotextile silt curtains were installed over the wash walls to protect any crayfish that remained while dredging was undertaken. The removal of silt from the canal will improve the overall quality of the habitat for crayfish.

Where habitat loss was unavoidable because the old wash-walls had to be replaced, new refuges were created using a variety of techniques and materials.

- To replace habitat lost during reparation of stonework, sections of plastic pipe 1 m long and 4.5 m in diameter cm were attached to repaired washwalls below the water level., and along the wall of a new bridge below the fender. Holes were drilled into the sides to create additional access points. They were placed 0.5 m above the canal bed to minimise the risk of blockage by silt. 'Scramble nets' were constructed from 2 inch plastic mesh, battened to the wall, to enable the crayfish to climb into the pipes.

- On the offside bank (the side opposite the one with the towpath), stones that had been removed from the channel, or obtained from the demolition of original structures, were placed in the channel shoulders and in mid-channel below navigable depth.

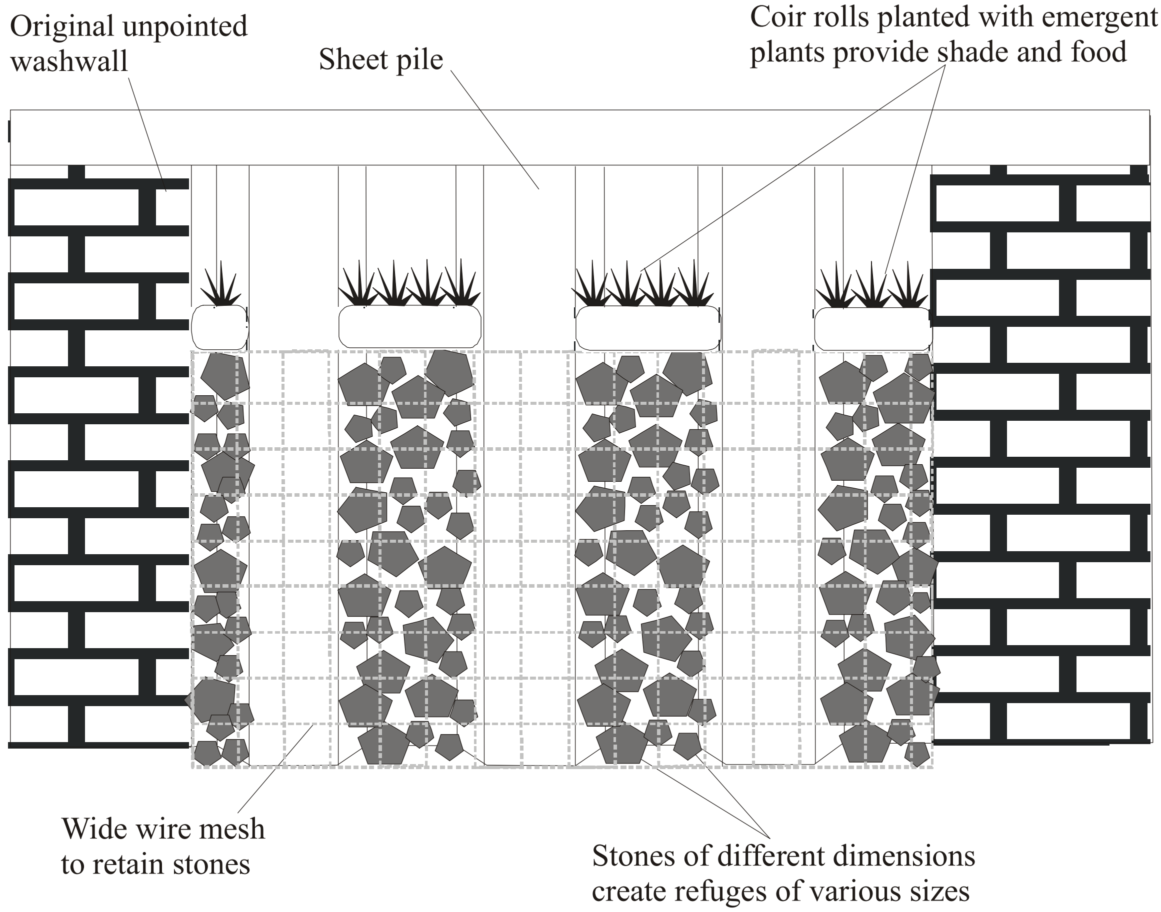
- Where sheet piling had been used to stabilise the banks, the area between the piling and the concrete canal liner was filled with rip-rap, and 5 cm gaps were left between the sheets to encourage access by crayfish.

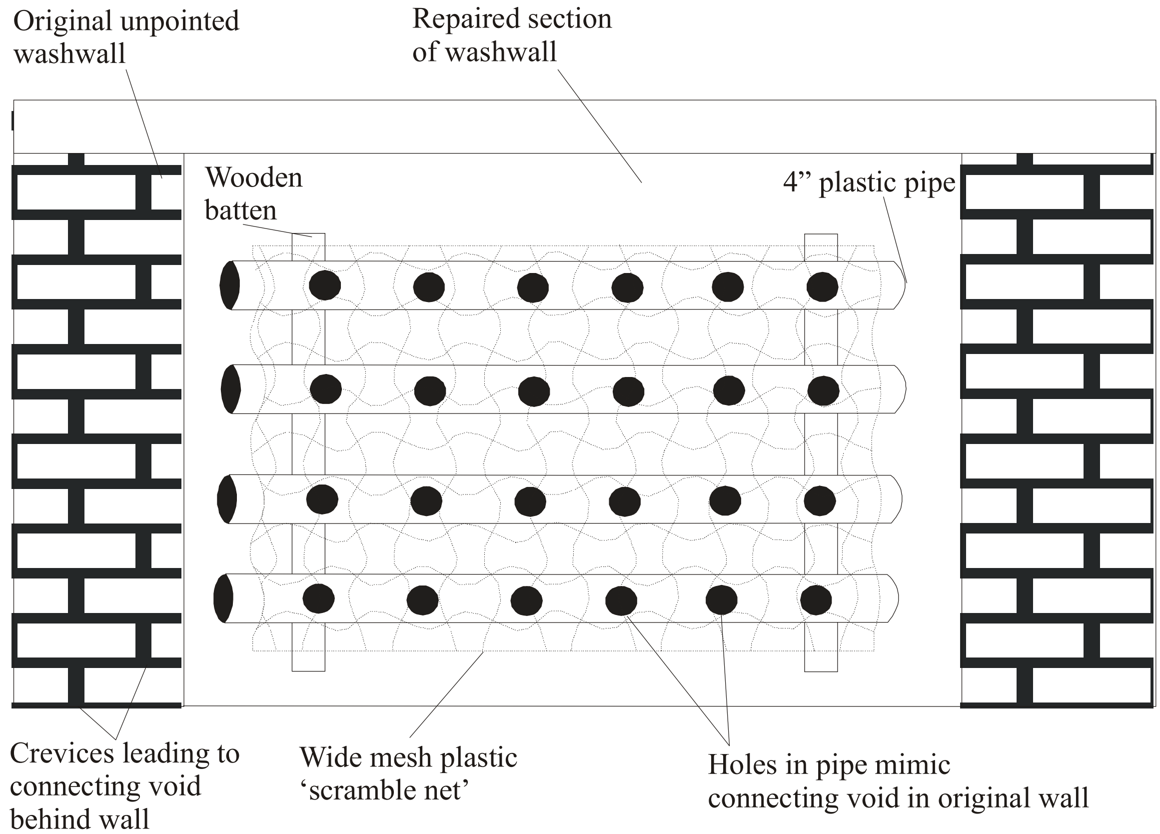
Success of scheme

Due to the difficulties of surveying for crayfish in deep water, little information is available on the success of specific crayfish enhancements. However, surveys carried out one year after works revealed that the population had expanded in both range and local abundance. A night-viewing survey carried out in August 2002, using an underwater periscope, recorded two crayfish utilising pipe and mesh refuges during the session.

Habitat enhancement features and the general status of the population will continue to be monitored by British Waterways. A specific survey of sheet piling refuges is planned for autumn 2002.

Diagrams showing two different methods used follow:


Original unpointed
washwall
Sheet pile
Coir rolls planted with emergent
plants provide shade and food
Wide wire mesh
to retain stones
Stones of different dimensions
create refuges of various sizes


Original unpointed
washwall
Repaired section
of washwall
Wooden
batten
4” plastic pipe
Crevices leading to
connecting void
behind wall
Wide mesh plastic
‘scramble net’
Holes in pipe mimic
connecting void in original wall

River Itchen

This project was coordinated by Adrian Hutchings, Sparsholt College, Hampshire.

This project was carried out in a small headwater tributary of the River Itchen. White-clawed crayfish downstream of the site are threatened by signal crayfish in the main river. Downstream migration of the native population would speed up the inevitable mixing of the two populations. The potential for upstream migration was limited by a section of channel with little suitable crayfish habitat. In this section the channel bed was composed primarily of chalk and gravel. The flow was slow and substantial amounts of silt had built up on the banks. This combination of gravel substrate and siltation meant that few suitable refuges were present.

Sites both up and downstream of this section contained favourable crayfish habitats and sustained populations of white-clawed crayfish, which used both in-channel stones and bank-side burrows as refuges. The enhancement site itself did not have crayfish present. Works were intended to enhance conditions at this site, encourage upstream migration and discourage downstream migration.

Works undertaken

Refuges were created in the channel by placing 60 tonnes of chalk flints over a gravel substrate, as this had been found to be the most important type of refuge in the area. The lumps of flint were placed so that they emulated features utilised by crayfish in the main river. Care was taken to ensure that suitable refuges for different sizes of crayfish in the population. Crypt-type refuges were made for adult crayfish by placing individual stones on two smaller supporting stones, leaving a small void beneath. Smaller refuges were made for juveniles in the shallow margins.

Hazel faggots were installed on the opposite bank to the newly created refuges to slightly speed up the flow. This was to decrease the amount of suspended sediment deposited in the area. The aim was to reduce the risk of refuges becoming blocked by silt in the future.

To further reduce the risk of siltation, semi-permanent fencing was installed on the banks to prevent trampling by grazing cattle. This also helped prevent the newly created features from becoming damaged. Trees and shrubs were planted along the bank as a food source for crayfish and to create additional refuges.

Success of scheme

It was anticipated that colonisation of the features by native crayfish would take place slowly, as the River Itchen population migrated upstream. Regular monitoring was carried out by manual survey and three years after completion of the project crayfish were recorded for the first time at the site, using the newly created refuges.

Dowdswell Reservoir

Coordinated by Carlos Abrahams, Environment Agency

Native crayfish have previously been reported in high numbers within Dowdswell Reservoir. Many crayfish were found in water that had been pumped out of the reservoir during construction of a new spillway in the late 1980's. Since that time crayfish sightings became less frequent and trapping studies carried out in 1997-1998 detected significantly fewer crayfish than were recorded in previous studies.

Over the past 15 years Dowdswell Reservoir has become increasingly silted. Draining the reservoir revealed a featureless landscape of silt across its whole bed, with few suitable refuges for crayfish. Essential engineering works were required to maintain the reservoir, and these necessitated that crayfish rescue be carried out to avoid loss of the population as a result of these works. As mitigation for this disturbance it was decided to improve crayfish habitat within the reservoir.

Works undertaken

Prior to commencement of works, crayfish in the reservoir were trapped, removed and kept in holding cages in an adjacent filter pond.

On the recommendation of Crayfish Consultants International Ltd, approximately 200 tonnes of limestone boulders (200 to 500 mm in diameter) were placed around the valve tower and along the inlet stream channel on the south shore. These stretched from the lowest possible to the highest water levels, thus creating favourable habitat whatever the water level. The limestone would also help to raise the calcium content of the water. The inlet stream beside the valve tower was redirected. This allowed a flow of oxygenated water through the boulders, to cleanse the rocks and prevent excessive siltation. Details of the works are shown in the diagrams below.

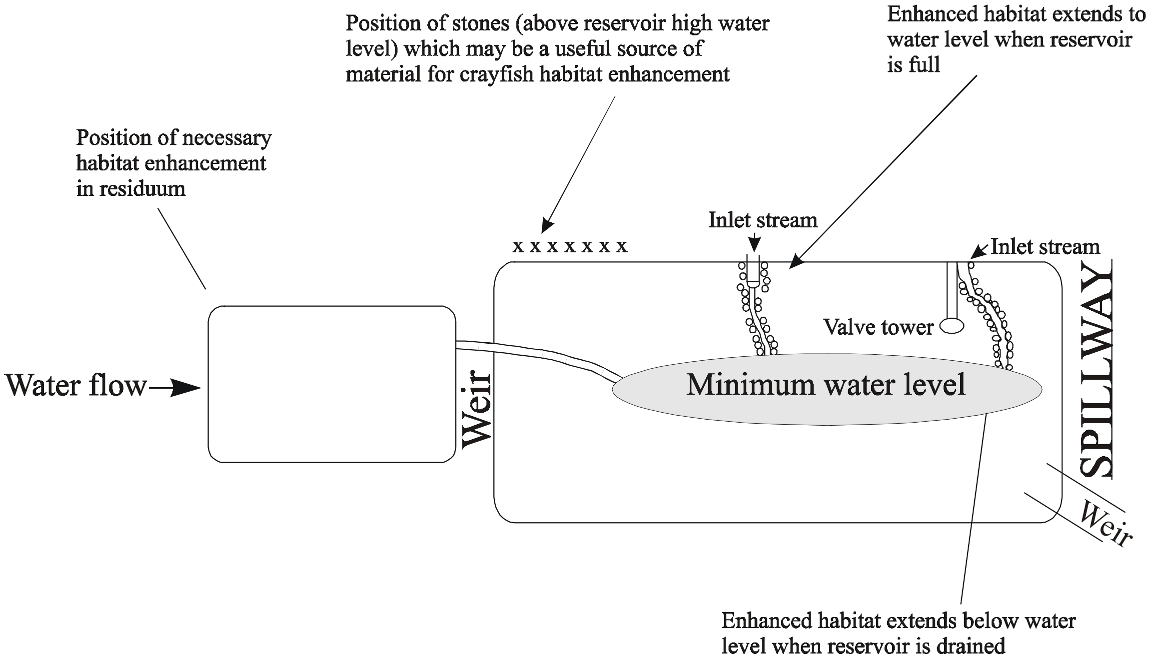
After completion of the engineering works, and the partial filling of the reservoir, crayfish were re-introduced to the enhanced areas.

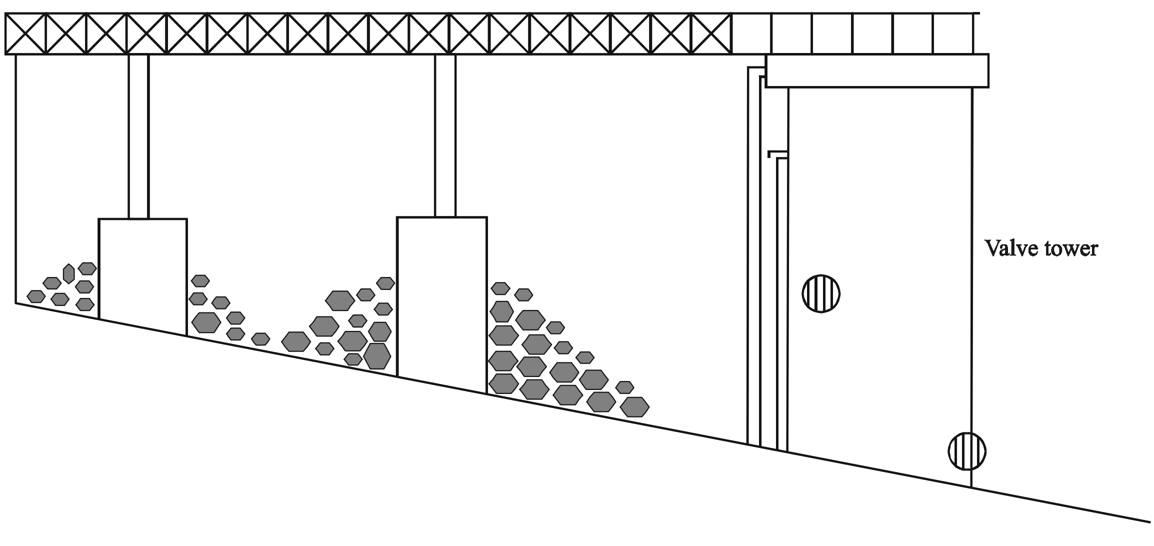
Progressive drawdown of the water supply reservoir occurs annual in the summer months, exposing extensive areas of refuges and so making them unsuitable for use by crayfish until the reservoir refills in the winter. Works are now focused on the creation of ponds at the upstream end of the reservoir. This will ensure that some areas of standing water (with favourable habitat for the crayfish) remain at all times of year.

Success of scheme

The success of habitat enhancement at Dowdswell Reservoir will be monitored in future trapping studies.

Dowdswell Reservoir





Habitat Creation in a Pond in Kirklees

Coordinated by Jeff Keenleyside of Kirklees Environment Unit

The site is a disused duck pond in the grounds of a stately home on the outskirts of Leeds. The site has no inflow and the only outflow is to a moat around the edge. The pond is concrete lined and contained no available refuges prior to the commencement of this scheme. No crayfish were present on the site prior to works.

A population of white-clawed crayfish in a local canal was under threat from an invading population of signal crayfish that was approximately 5 km downstream. Engineering works on part of the canal necessitated removal of the native crayfish. It was decided to create suitable habitat at this pond and populate it with some of these native crayfish, rather than return the rescued crayfish to the threatened population. Guidance on the (re-)introduction of white-clawed crayfish is given in Scott Wilson (2002).

Works undertaken

Sandstone was reclaimed from the grounds of the stately home for reuse in habitat creation in the pond. Large cobbles were collected and washed to remove excess sediment and piled around the pond margins so as to create refuges of different sizes for juvenile and adult crayfish. Chemical analysis of the pond water was carried out, and indicated that the water chemistry was suitable for crayfish.

Following the crayfish rescue, crayfish from a range of size classes including year 1+ and 2+ juveniles, adult males and adult females were selected for translocation. Several females were in berry, ensuring that the structure of the introduced population would mimic the age and sex ratios expected in nature. Crayfish were acclimatised to the pond water gradually by exposure to the water in buckets for increasingly prolonged periods before finally being introduced to the new pond.

Success of scheme

A crayfish survey carried out three months after the introduction to assess the success of the translocation found that crayfish were still present in the pond. A further brief check carried out the following year discovered berried female crayfish, indicating that the pond now supports a breeding crayfish population. Further monitoring will be carried out to help ensure the continued success of this translocation.

River Darent

Coordinated by Rob Mungovan, Environment Agency.

Native crayfish were widespread in the River Darent until 1988, when a suspected outbreak of crayfish plague led to the loss of all but a few isolated populations on the headwaters and tributaries. A reach of the river identified as a key site for native crayfish in the Darent catchment was subject to engineering works. A collaborative project was carried out by the Environment Agency, the landowner and the North West Kent Countryside Project to enhance crayfish habitat in this section of the river. Prior to enhancement, this reach of the River Darent was essentially ornamental and landscaped. The average width of the channel was 3.2m and the average depth 0.02m. The main substrate was gravel with some cobble, the flow was slow and the bed was highly silted. The favourable conservation status of the native crayfish at this site was compromised by the lack of favourable refuges and siltation of those that were present.

Works undertaken

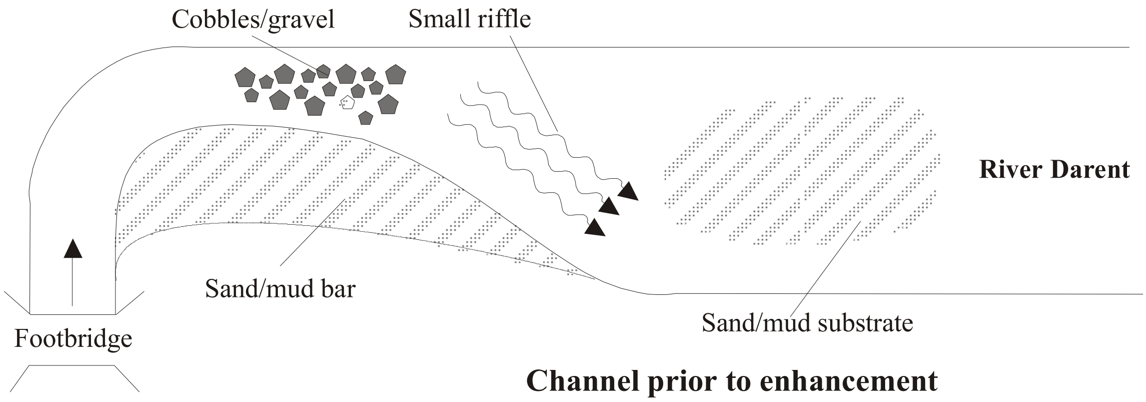
To treat the problems of lack of refuges and siltation, a low-level aquatic ledge (or berm) was constructed to provide crayfish refuges and to narrow the channel. This would have the effect of slightly increasing the flow, decreasing the amounts of silt deposited in the area. Crayfish likely to be adversely affected by the works were rescued under the supervision of a licensed crayfish worker.

The ledge was constructed from graded local stone and was retained by chestnut posts driven into the bed at approximately 0.2 m intervals, following the existing contour of the bank. A pair of A-wing deflectors (see figures below) were incorporated into the design, by using horizontal posts fixed to the verticals with 0.2 mm Netlon plastic-coated wire. The posts were cut to about 1.5 m above the normal water level.

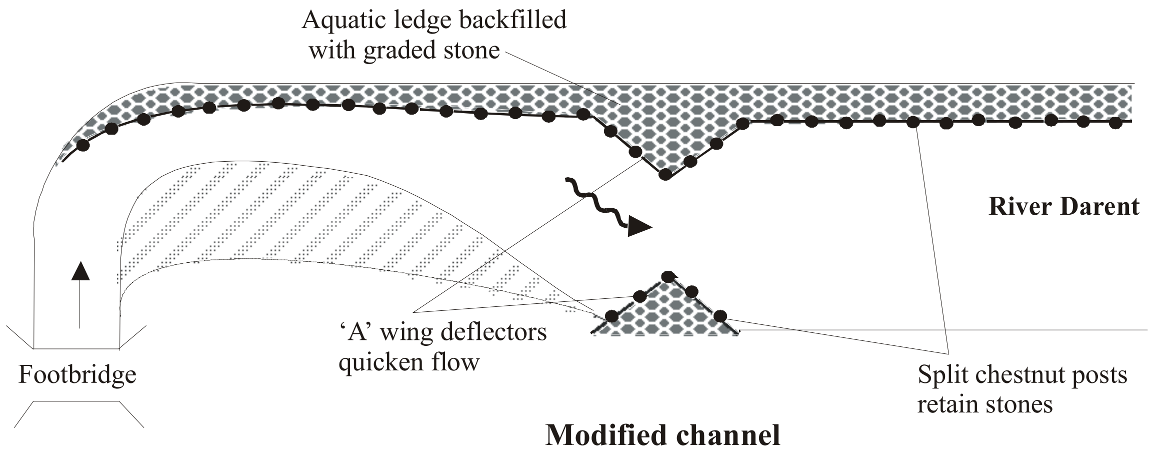
Stone was provided by the landowner and was washed to remove excess sediment before being graded into sizes. Stones were positioned behind the posts to create a range of refuge sizes and an overhang. Stones of approximately 0.1 m diameter were scattered onto the streambed behind the posts and relatively square, flat stones of approximately 0.2 m diameter were placed on top. More stones of a progressively smaller size were used to fill the void up to the top of the posts. These small stones were intended to prevent fine sediments from being washed down into refuges below and to provide a matrix in which vegetation could become rooted.

Success of scheme

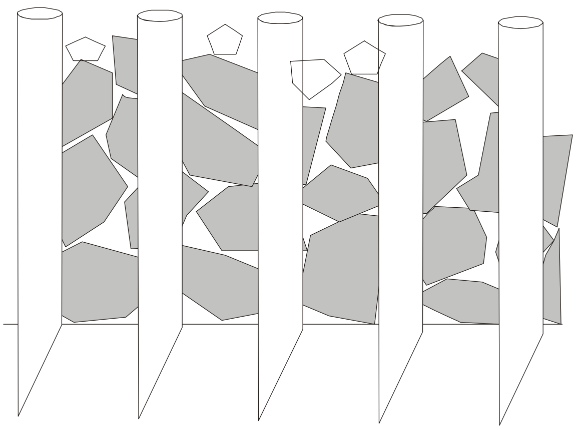
No information is available as yet on the success of works, but future monitoring will compare the newly created feature with a section of unmodified channel. Future enhancement possibilities include the extension of the ledge and the placement of geotextile matting on top of it to encourage vegetation to colonise the surface.



Channel prior to enhancement



Modified channel



Long Preston Beck

Coordinated by Graeme Hull, Nuttalls Ltd.

The Settle and Carlisle railway line crosses a number of tributaries of the River Ribble. At Long Preston, near one of the railway bridges, a high, steep section of stream bank started actively eroding. If left unchecked, this would cut in to the railway embankment. Works were necessary to reinforce approximately 70m of stream bank.

The stream was known to have a population of white-clawed crayfish. This was confirmed in a standard survey (Peay, 2002) prior to the start of the project. Crayfish were found in a slow-flowing glide at the upstream end of the site. Most of the section affected by the works was a fast-flowing riffle and the unstable left bank meant that material was continuously eroding from the steep slopes. Crayfish were at too low abundance to be recorded in this area.

Works undertaken

A rescue of crayfish was undertaken at the start of the works. This involved removing all the cobble and boulder from the bed of the channel in the area affected by works. Clearance was carried out by a crayfish surveyor aided by a couple of helpers, with a work rate of around 20 minutes/m^2. There was a lot of stone to clear per unit area, but only a low density of crayfish in the margins downstream of the glide (c.1 in $5m^2$). The crayfish were relocated immediately upstream of the working area in the glide, where there were plenty of refuges in the banks and channel. Very large sandbags were lowered into the channel to slow the flow and largely blocking the working area from crayfish upstream. All the stone removed was stored in the site compound for use in reinstating the channel. A shallow berm was dug along the margin and this and the eroding bank were covered with a geotextile. Blocks of locally quarried stone about 600mm long were laid on the berm. The first layer was partly below the usual water level during low flows. The space behind each row of blocks was back-filled with graded stone and finished with fill excavated from the bank. In the margins at the foot of the block wall the boulders and cobbles removed during the crayfish rescue were loosely arranged, providing refuges in the slightly deeper and slower-flowing water immediately adjacent to the bank. The stone blocks provided submerged crevices. Photographs taken before and after the works are shown below.

Success of scheme

The works were only completed in 2002, but crayfish surveys are planned in 2003 to see if the abundance of crayfish has increased next to the new bank.

Long Preston Beck, actively eroding bank

Detail of reinforced bank showing new submerged crevices and reinstated channel

River Leith

Coordinated by Alistair Brock, Eden Rivers Trust

The River Leith used to be good for salmonids and has a good crayfish population. Land management practices in the catchment were thought to be having a negative impact on salmonid numbers and crayfish. Much of the riverbank was denuded by grazing stock. Adjacent woodlands were heavily grazed with no regeneration. In winter large amounts of silt enter the river from fodder beet fields on the adjacent plateau, as well as from eroding riverbanks and from fields used as winter-standing for cattle.

Midtown Farm suffered from all of these factors. Cattle churned up a field used for winter feeding, creating large amounts of mobile silt that entered the river. They also regularly trampled the river bed. The banks were eroding, the river bed appeared to be over widened and the water was extremely shallow in depth, even stopping in normal summer conditions. There was little pool/riffle morphology and the river bed was pretty uniform throughout its length only relieved by the presence of large limestone blocks and cobble, which provided reasonable cover for crayfish.

The new tenant who took over the farm in 1996 was keen to farm in an environmentally friendly manner. He was having a problem with Leptospirosis in cattle, which helped in his decision to have the whole river fenced off. The aim of the project was to remove stock grazing from about 1.5 kms of riverbank; to create a buffer zone between the farm and the river, and to facilitate the regeneration of a wide range of river side, woodland and small wetland habitats. The hope was that this would lead to the recovery of salmonid fry populations and reduce impact on crayfish.

Works undertaken

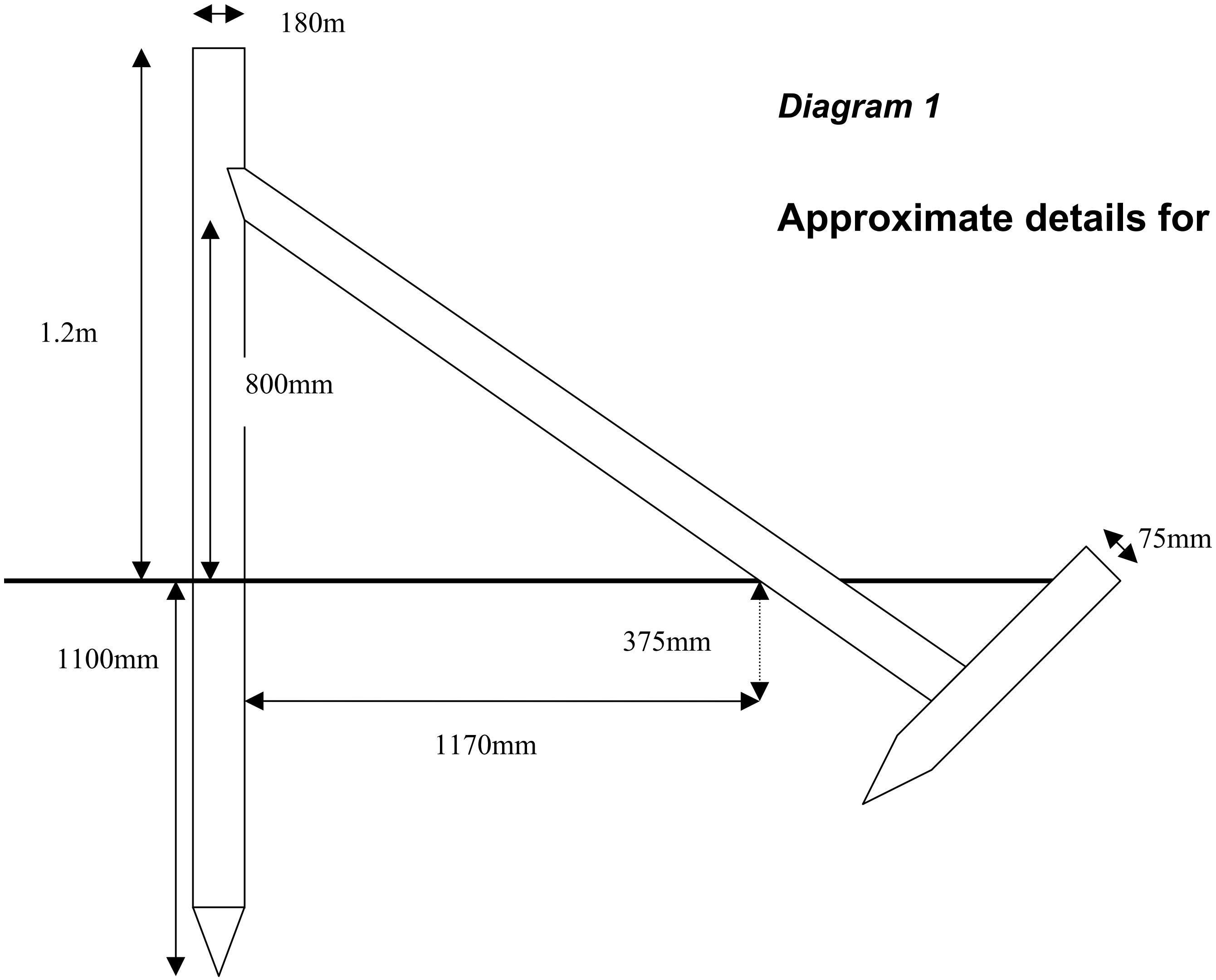
1250 metres of new fencing was installed about 6 metres from the top of the riverbank, or more around woodland (see diagrams). 1ha of existing woodland and 0.4ha of new woodland were included in the scheme. These were fenced and replanted with about 1000 trees. Gates were provided for access. A new mains water-supply was provided for stock.

Success of scheme

There has been excellent recovery of vegetation in all situations. The river has narrowed by up to a third in places, due to the growth of marginal plants. This is leading to an increased diversity in the river characteristics with a perceived increase in pool/riffle sequences. The majority of eroding banks have stabilised with good vegetative cover at their toes and the banks are becoming covered in moss and algae – a good sign that they are no longer eroding. No improvement was seen in the salmonid fry populations on this project when data was collected in 2000 and 2002, but there is some evidence that there are greater fry numbers downstream where another 5km of bank protection work has been undertaken, possibly a cumulative effect. There is no information on crayfish numbers but there appears to be a healthy population from casual stone turning.

Diagram 1

Approximate details for the setting up of the strainer



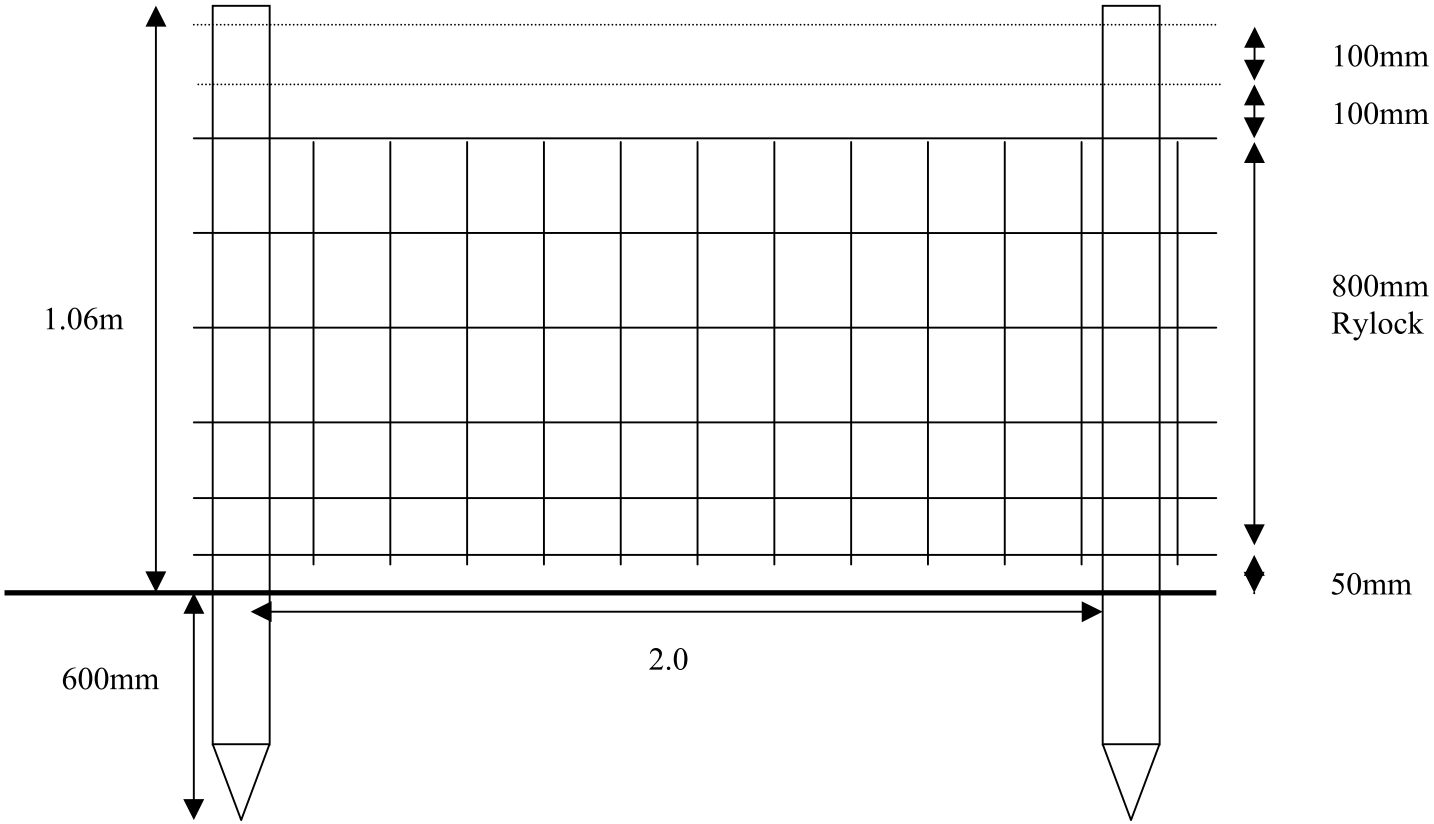


Diagram 2

Rylock, 2 strand barbed wire

Rylock with 1, 2 barbed wire Woven wire fencing (BS 1722 pt 2)

- It shall be galvanised (BS 4102), standard height green rylock net C8/80/15.
- Shall not be less than 1.06m high from ground to top wire
- Straining Posts shall be 180mm minimum top diameter x 2.4m's to be driven into the ground.
- Strainers to be set at centres not exceeding 50m's.
- Turning posts shall be 155mm top diameter x 2.1m's. May be pointed and driven to 900mm into the ground.
- Struts shall be 120mm dia x 2.1m long and notched into the straining post at an angle no greater than 45 degrees. Allow two struts for strainer/turner where angle is less than 135 or one bisecting the angle where the internal angle is greater than 135.
- Intermediate post shall be 75 - 100mm dia x 1700mm to be driven to 450mm. To be set at no more than 2.0 m intervals.

River Leith, Midtown Farm, September 1997; over-wide, trampled, with no in-stream vegetation.

River Leith, Midtown Farm, July 1999 in second year after fencing; abundant marginal vegetation, good growth of water crowfoot.

Appendix 2 contacts

Table A2 Licensing Authorities for White-clawed Crayfish

Country	England	Wales	Northern Ireland
Licensing agency for white-clawed crayfish	English Nature (EN)	Countryside Council for Wales (CCW)	Department of the Environment for Northern Ireland (DoE (NI)*
Address	English Nature Licensing Section Northminster House Peterborough PE1 1UA	Countryside Council for Wales Mae y Ffynnon Ffordd Penrhos Bangor Gwynedd LL57 2DN	Environment and Heritage Service, Natural Heritage section Commonwealth House 35 Castle Street Belfast BT1 1GU
Telephone	01733 455000	01248 385500	028 9025 1477
Email	enqiries@english-nature.org.uk	enquiries@ccw.gov.uk	NH@doeni.gov.uk

*DoENI deals with licensing of work on protected species – white-clawed crayfish will be included in future.

Addresses and telephone numbers of the local offices of the statutory agencies are given on their respective web-sites, as follows:

- http://www.englishnature.org.uk/
- http://www.ccw.gov.uk/
- http://www.doeni.gov.uk/
- http://www.environment-agency.gov.uk/

1. Slow flowing area of stream with lots cobble and boulder, overhanging trees. This site gets slight enrichment from urban runoff, but is still very suitable for crayfish.

2. Boulder-filled pool below undercut tree. Large roots below water give flood-resistant refuge.
3. Glide in upland river, with abundant cobble and good growth of *Fontinalis* moss.

4. Debris dam in steep section of a rocky stream. Crayfish hide among branches and leafpacks.

5. Crayfish use areas of canal where there are remains of old bank reinforcement, rubble and emergent vegetation.

6. Old canal wash wall with high density of crayfish.

7. Shallow, fast-flowing riffle in stony stream, with most stone deeply bedded and inaccessible. A few loose stones provide refuges. In this stream, an abundance of good refuges means this riffle is poor quality habitat, subject to frequent high flows. In other streams with few refuges, the few boulders with cavities are more likely to be occupied.

8. Bank of pebble and small cobble, which is frequently exposed in variable flows of this large limestone river – poor habitat for crayfish, even for juveniles.
9. Fine roots of alder – good for juveniles when fully covered, but these ones are very frequently exposed in summer. These roots have best potential in autumn to spring.

10. Side pool of stream, with good potential refuges, but ochre seepage from base-poor spring means it is not used by crayfish.

11. A clay stream with trampled banks, muddy bed and growth of algae. It is poor for refuges, but may be used by small numbers of crayfish, mainly juveniles, or by adults for feeding.

12. New concrete wall has removed bankside habitat for crayfish.


13a. Just after fencing of banks, view in May


13b. Revegetated banks, view in July, one year later


14a. Cumbrian river with grazed banks and erosion, view in May.


14b. Same site in July, one year later, eroded areas recovering.

Effects of fencing riversides: photographs on this page were kindly provided by Alasdair Brock, Eden Rivers Trust, Cumbria.