SCOTTISH NATURAL HERITAGE

COMMISSIONED REPORT

Commissioned Report No. 014

Strategy for the containment and possible eradication of American signal crayfish (*Pacifastacus leniusculus*) in the River Dee catchment and Skyre Burn catchment, Dumfries and Galloway

(ROAME No. F02LK05)

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Summary

Strategy for the containment and possible eradication of American signal crayfish (*Pacifastacus leniusculus*) in the River Dee catchment and Skyre Burn catchment, Dumfries and Galloway

Commissioned Report No. 014 (ROAME No. F02LK05)
Contractors: Galloway Fisheries Trust

Background

Since the first confirmed report of North American Signal crayfish (AS crayfish) in the Kirkcudbrightshire Dee in 1996 it has become apparent that the species has continued to expand its range within this catchment from the initial introduction points. Prior to this study there were only three known Scottish populations of AS crayfish.

A number of biodiversity concerns are related to the presence of AS crayfish, these include the introduction and spread of crayfish plague (*Aphanomyces astaci*), competitive exclusion of native White Clawed crayfish, changes in local flora/fauna through grazing and predation, habitat degradation through burrowing and refuge competition with salmonid fish.

This report aims to investigate and develop the potential for the containment and possible small-scale eradication of the AS crayfish population of the Kirkcudbrightshire Dee and a new population found in Dumfries and Galloway. The work included a literature review, questionnaire study and trial of methodology.

Main findings

- A circulated questionnaire indicated that many locals are aware of AS crayfish presence in the Kirkcudbrightshire Dee catchment and the environmental damage they can cause. There was a strong feeling that AS crayfish should be controlled, that trapping is already being undertaken extensively and that local catering establishments are selling them. Little was known of relevant Scottish legislation.
- AS crayfish distribution in the Kirkcudbrightshire Dee had increased since previous studies and now covers the Water of Ken and tributaries from Earlston Dam down to the upper 5km of Loch Ken. A new Scottish population was discovered during this study in the Skyre Burn, near the Water of Fleet.
- On the Kirkcudbrightshire Dee the suggested containment strategy includes trapping the Water of Ken. A study using traps on the Garple Burn found limited success due to water depths and winter AS crayfish behaviour.

- The construction of an elver fish pass at Tongland Dam would allow this important AS crayfish predator to gain access to both Loch Ken/Water of Ken area.
- Experimental work using modified traps to catch smaller AS crayfish was inconclusive and needs further work.
- On the Skyre Burn catchment a possible eradication strategy has been suggested which would involve electrofishing the Lagganmullen Burn and trapping the ponds linked to the Lagganmullen Burn and the Lower Skyre Burn.
- A general education programme, regarding AS crayfish and to publicise legislation, focussing on local land, owners, catering establishments/suppliers, anglers and children is proposed.

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The GFT would also like to thank the landowners who allowed us to access through their land for trapping and electrofishing sites.

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Strategy for the containment and possible eradication of American signal crayfish (*Pacifastacus leniusculus*) in the River Dee catchment and Skyre Burn catchment, Dumfries and Galloway

Commissioned by: Scottish Natural Heritage

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1 INTRODUCTION

The North American Signal crayfish (AS crayfish) *Pacifastacus leniusculus* is not native to the British Isles. The species was introduced from the western states of North America to Sweden in the 1960's. Large numbers have been introduced to Britain from mainland Europe since the 1970's, predominantly for farming (Holdich & Reeve 1991).

It is believed that the AS crayfish is responsible for the introduction and spread of the crayfish plague, caused by the fungus *Aphanomyces astaci* (Palmer 1994). While AS crayfish do not find this disease fatal it has devastated populations of the native White Clawed crayfish *Austropotamobius pallipes* across England and Wales (Holdich & Reeve 1991). AS crayfish have also eliminated populations of White Clawed crayfish through competitive exclusion (Holdich & Domaniewski 1995; Reynolds 1998).

AS crayfish are large omnivores and may cause significant changes in local flora and fauna through grazing and predation (Maitland *et al*. 2001). They can also contribute to habitat degradation through burrowing (Holdich & Rogers 1995; Maitland 2001) and can compromise the structural integrity of riverbanks (Sibley, in Rogers & Brickland 2000). AS crayfish may feed on aquatic invertebrates, fish eggs, fry and larger fish. Introduced AS crayfish are therefore likely to compete with insectivorous fish for food and predate on all life stages of resident fish when the opportunity arises. Laboratory studies have also demonstrated competition for refuges between AS crayfish and juvenile salmon.

As non-native crayfish species spread increasingly across Europe, there is an urgent need for methods of control and eradication to be developed (Holdich *et al*. 1999).

1.1 Crayfish in Scotland

No species of crayfish is native to Scotland, although at least five populations have become established (Maitland *et al*. 2001). Each population is significant in terms of freshwater conservation in the UK. Populations of White Clawed crayfish have been recorded in the Durness area of Sutherland (Thomas 1992) and in the lower Clyde catchment (Maitland *et al*. 2001). These populations have considerable conservation value as they represent a source of disease free crayfish that may be useful for restoring native populations in England and Wales. The remaining three Scottish populations consist of AS crayfish, whose presence is undesirable for reasons discussed above. These populations were recorded in the upper River Clyde (Maitland *et al*. 2001), the Kirkcudbrightshire Dee catchment (Maitland 1996; West Galloway Fisheries Trust 1996 & Sinclair & Ribbens 1999) and the River Earn (Maitland *et al*. 2001). In Scotland, there is a particular concern about potential impacts on brown trout *Salmo trutta* and Atlantic salmon *Salmo salar*. Although little research has taken place, it has been demonstrated that juvenile salmon can be excluded from their refuges by AS crayfish (Colin *et al*. 2002).

1.2 Purpose of present study

This report was commissioned by Scottish Natural Heritage (SNH) and completed by the Galloway Fisheries Trust (GFT). It was undertaken as a follow-up to a SNH report commissioned in 1999 (F99AC601) entitled

'Survey of American Signal crayfish, *Pacifastacus leniusculus*', and to previous survey work that has been completed on AS crayfish.

The present study was developed to investigate the potential for containment and small-scale eradication of AS crayfish populations within the Kirkcudbrightshire Dee catchment using established and new methods. During the course of the project a new AS crayfish population was recorded in the Skyre Burn, near Gatehouse of Fleet, and the remit of the report was expanded to include this new population. This study was carried out between September 2002 and March 2003. The aims of this study are presented in **Section 2.**

2 AIMS

The aims of this study were as follows:

- To produce a comprehensive review of available literature on containment and eradication methods developed for AS crayfish.
- To produce a review of current legislation regarding AS crayfish, especially that which falls under Scottish law.
- To review approaches and methods of control applied elsewhere in Scotland, where a similar AS crayfish problem exists.
- To produce and distribute a questionnaire to gauge the level of public awareness of AS crayfish within the Kirkcudbrightshire Dee catchment. The questionnaire was also used to collect important information on AS crayfish presence and distribution within the Ken/Dee system.
- To develop containment and small-scale eradication methods for use in areas of known AS crayfish infestation in Dumfries and Galloway.
- To implement and trial aforementioned methods described in Section 2.5.
- To produce a strategy for the control/eradication of AS crayfish in Dumfries and Galloway.

3 LITERATURE REVIEW

3.1 Aims and Objectives

The aim of this section was to review methods suitable for the containment and small-scale eradication of AS crayfish within Dumfries and Galloway, which could also be applied elsewhere. Legislation relating to AS crayfish and their control has also been reviewed.

Much of the information used in this literature review was obtained from widely published work. However, an increasing number of control methods are being developed, the results of which have yet to be formally published. Therefore, a range of information sources has been used in this review, including conference papers and internal reports.

3.2 Containment and Eradication Methods

Holdich *et al*. (1999) suggest that when evaluating approaches for the control of AS crayfish, the following points should be considered:

- effectiveness
- environmental impact
- human safety
- public acceptance
- cost
- effort required.

Effectiveness can be measured as the success with which AS crayfish of different sizes and sexes are removed from different habitat types. Some methods may cause considerable damage to the freshwater ecosystem and it is vital that potential environmental impacts are explored. The safety of those undertaking any control work and that of the general public are prime considerations, particularly when chemicals are used. Public opposition may arise from any work that causes environmental damage, health concerns and loss of amenity. It is important to identify potential public objections and to consider whether the impacts resulting from each method can be justified. The resources available for any program of work ultimately dictate whether it is viable and it is therefore important to consider costs of equipment, transport, human resources and training. Where possible, these points have been considered for each of the approaches discussed in this review.

There are two recent reviews of methods for controlling AS crayfish: Holdich *et al*. (1999) and Peay (2001). Both highlight five broad categories of methods that may be used for controlling AS crayfish: Legislative, Mechanical, Biological, Chemical and Physical. This review examines the viability of methods in each of these categories and discusses their suitability for use within the Kirkcudbrightshire Dee and Skyre Burn catchments.

3.2.1 Legislation

Section 14 of the Wildlife and Countryside Act 1981 provides basic legislation against the release of non-native species into the wild. In 1992, *P. lentiscus* was included under part I, Schedule 9 of this act because of its potential environmental impacts and threat to populations of White Clawed crayfish *A. pallipes*. Schedule 9 lists species that are not native to Britain but have established feral populations in some areas. In Britain, it is therefore an offence to release AS crayfish into the wild. On its own, this legislation is widely regarded as insufficient for restricting the spread of AS crayfish. There is no clear definition of "wild" and proving AS crayfish have been released is extremely difficult unless directly observed.

3.2.1.1 Scotland

Under advice from Scottish Natural Heritage, new legislation was introduced in Scotland. The Prohibition of Keeping of Live Fish (Crayfish)(Scotland) Order 1996 makes it an offence to keep non-native crayfish in Scotland without a license granted by Scottish Ministers. However, markets, hotels and restaurants are exempt from this order and may keep non-native live AS crayfish if they are intended for human consumption. Those involved in the legal AS crayfish trade have been issued with guidance material informing them of the dangers posed by non-native crayfish and their responsibilities regarding their storage and transportation.

As part of an action plan to protect native freshwater crayfish populations, the Joint Nature Conservation Committee (JNCC) recommended in 1994 that in addition to the use of the Wildlife and Countryside Act 1981, the keeping of all species of live non-native freshwater crayfish within Scotland should be further controlled by the Import of Live Fish (Scotland) Act 1978. The 1978 Act allows the Scottish Ministers, by order; "*…to forbid either absolutely or except under licence….the keeping or release in Scotland of live fish or the live eggs of fish, of a species which is not native….and which…might compete with, displace, prey on or harm the habitat of any freshwater fish, shellfish or salmon in Scotland*". The prohibition of import, keeping or release depends on the making of Orders naming the fish to be excluded. Only three such Orders have been made to date and one of these involves the introduction of non-native crayfish species suggesting that crayfish should be treated as other 'fish' species. In England DEFRA have legally interpreted crayfish as "fish" which means permission is also required from EA under Section 30 of the Salmon and Freshwater Fisheries Act (1975). However, S30 is not relevant to Scotland, and no such parallel provisions exist.

The 1994 JNCC report also suggested that SOAFD (now SEERAD) should formally recognise 'no-go' areas, where the keeping of live freshwater crayfish of any species would be subject to stringent control by licensing under the Import of Live Fish Act. Further, the report recommended that the whole of Scotland should be recognised for the keeping of live crayfish. By making of the Prohibition of Keeping of Live Fish (Crayfish) (Scotland) Order 1996, it is clear that Government have recognised the problems associated with signal crayfish introduction.

In the Salmon and Freshwater Fisheries (Protection) (Scotland) Act 1951, the word "fish" is not defined. Therefore this act does not apply to AS crayfish. This is unfortunate as the act prohibits fishing for or taking freshwater fish in inland waters, unless by rod and line. This would appear to prohibit gathering fish by hand, although trapping non-salmonids is permitted with the agreement of the proprietors or occupier of the fishing rights.

It is illegal to keep crayfish under the 1996 Order, therefore having them in your possession without a license during transportation is illegal. Once you have illegally transported your crayfish to your chosen destination is also illegal to release them under the Wildlife and Countryside Act 1981. In the advisory leaflet originally published by MAFF and distributed in Scotland, guidelines are given for the safe transport of AS crayfish. However, no indication is given of who may legally transport them.

It is unclear which agency is responsible for enforcing the legislation discussed above. Section 2 of the Import of Live Fish (Scotland) Act 1978 provides that while any order made under Section 1 of that Act is in force, any officer commissioned by the Commissioners of Customs and Excise, or a person duly authorised by the Scottish Ministers may at all reasonable times, on production of his authority if so required, enter and inspect any land occupied by a person holding a licence granted under that section and any other land upon which he has reason to believe that live fish, or the live eggs of fish, of the species specified in the order are being kept or may be found. It is likely that the Scottish Executive would be responsible for initiating any legal action.

3.2.1.2 England and Wales

In England and Wales, similar legislation exists regarding the keeping of AS crayfish. However, the approach to trapping and enforcement of legislation differs compared to Scotland.

The Prohibition of Keeping of Live Fish (Crayfish) Order 1996 makes it an offence to keep non-native crayfish in England and Wales without a licence. These regulations do not apply to specified areas, where alien crayfish are already well established in the wild.

Following a legal ruling (Caygill vs. Thwaite 1985), crayfish were legally classified as a freshwater fish and are therefore subject to current fisheries legislation (Chambers, in Sibley *et al*. 2002). Under the Salmon and Freshwater Fisheries Act 1975, the trapping of AS crayfish is therefore illegal in England and Wales, unless authorised by byelaw.

In England and Wales, the Department for Environment, Food and Rural Affairs (DEFRA) are responsible for implementing this legislation and have adopted the policy of issuing a general licence to markets, hotels and restaurants for the keeping of non-native crayfish. Some CEFAS (Centre for Environment, Fisheries and Aquaculture Science) and Environment Agency staff have been issued warrants to enforce this legislation and to ensure no crayfish are imported illegally.

Despite the widespread dissemination of advisory documents by CEFAS and the Environment Agency, lack of awareness is still considered to be a major problem (Scott (2000), in Rogers & Brickland 2000). However, ignorance of the law is no defence against charges brought under this legislation.

3.2.2 Mechanical control

3.2.2.1 Trapping

Two trapping methods are reportedly used in attempts to control nuisance populations of AS crayfish: refuge traps and baited traps.

Refuge traps are intended to provide a preferential habitat for resting AS crayfish (Peay 2001). Individuals may enter and leave at will and are caught as the trap is removed from the water. No refuge traps have yet been commercially produced or used for control purposes on a large scale.

Much more commonly used is the "Swedish Trappy" (Holdich *et al.* 1995; Peay 2001), a baited trap designed to attract AS crayfish and prevent their escape. Two types of trappy are available commercially, a cylinder and a pyramid shaped box called the "Tetra" which is less commonly used. Both are constructed from a plastic mesh, with a conical entrance at each end and a weighted base. The diamond shaped mesh has internal dimensions of approximately 34 x 24mm in the standard trappy and 31 x 16mm in the tetra. Traps are commonly baited with either fresh fish or cat food. The spatial density of traps varies between projects and is often reported only as the number of traps used in a given length of river. Rogers and Loveridge 2000 used 90 traps to remove AS crayfish over a 100m long section of the River Ure, whilst Wright and Williams 2000 deployed 12 pairs of traps along 250m of the River Stour. Other examples are densities of 70 traps along 3.5km of the River Hamps and 30 traps along 100m of the Huddersfield Canal (Peay 2001). Similarly, different time periods are reported for trapping duration, from a few days to over a year (Wright & Williams 2000).

Although widely used in attempts to remove AS crayfish populations, trappies were designed for the sustainable harvest of AS crayfish. The mesh size is widely reported to allow AS crayfish smaller than 40mm carapace length to escape (Wright & Williams; Sibley 2000). These escapees could theoretically represent the majority of the population, many of which may be sexually mature (Smith & Wright 2000). To make trapping more effective in catching smaller AS crayfish, some studies report the use of modified trappies or the construction of traps from fine plastic mesh. Wright and Williams 2000 report significantly more small AS crayfish caught in fine (8mm) meshed traps compared to standard trappies and a size range of 19–72mm carapace length for AS crayfish captured using a combination of both traps. However, there are reports of a bias towards larger AS crayfish even when small meshed traps have been used. Holdich *et al.* (1999) suggests this may be a result of small AS crayfish avoiding these traps when larger AS crayfish are inside. It would therefore be desirable for small meshed traps to have an entrance that only permits small AS crayfish to enter. However, even traps with a 4mm mesh covering will not retain the smallest (0+ age class) AS crayfish (Sibley 2000).

A bias towards capturing adult males is widely reported and Sibley 2000 found strong evidence to support this. Intensive hand netting (a method not thought to have a bias towards one sex), revealed the proportion of males to females was 40:60. This was strikingly different to the ratios obtained from trapping, which ranged from 55:45–80:20. Wright and Williams 2000 suggest this bias is due to behavioural differences between the sexes, especially during the breeding season when females become less active.

Rogers and Loveridge 2000 report that characteristics of the River Ure such as fast flows and an uneven bed, made accessing traps difficult. Traps were emptied and re-baited weekly. It is inferred that the inability to check traps more regularly severely reduced the effectiveness of this method, although details are not given. AS crayfish are reported to be able to escape from traps with relative ease, often using them as a refuge during the day (Byrne *et al.* 1999). This confirms the view of Holdich that traps would be at their most effective when emptied frequently.

By trapping throughout the year, Wright and Williams 2000 demonstrated that the effectiveness of trapping varies seasonally. Average catches rose in April as water temperature increased. Numbers peaked during

the breeding season (August–October) and fell to their lowest level in January. Catches of males were considerably higher than females during this period. Male activity increased as they searched for sexually mature females who become less active as they become berried.

Holdich *et al.* (1999) discuss several studies where following sustained and intensive programs of trapping, catches have reduced significantly over time. However, estimating the effectiveness of any removal method is difficult due to difficulties in estimating the total population size. For example several methods require a closed population and within it, random mixing of individuals. Due to the behaviour of AS crayfish and the nature of the sites they have colonised, these criteria will rarely be met.

The effort (trapping intensity and duration) needed to substantially reduce AS crayfish populations is difficult to estimate due to the poor understanding of the relationship between the number of adults and reproductive success (Smith & Wright 2000). It is suggested that a moderate level of trapping may cause an increase in population size of AS crayfish, as the level of predation by cannibalistic males is reduced. The remaining females may also respond to a reduced population density by producing more eggs (Holdich *et al.* 1999; Sibley 2000). Higher levels of trapping may succeed in eliminating a population, if it reduces the adult stock to levels where reproduction is insufficient to replace AS crayfish that die or are removed. Such a program would have to take place over many years and it is unlikely to succeed unless the population is enclosed.

The environmental impact of trapping is likely to be low. Traps rarely catch anything other than AS crayfish (Holdich *et al.* 1999), although it is possible that fish and small mammals such as water voles could occasionally be caught.

Traps are relatively cheap (commercial price £7–£9) and can be re-used. However, for large scale control the cost may become prohibitive.

No trials of trapping have yet been proven to be effective in eradicating an AS crayfish population. However, it remains a potentially useful tool for controlling small or enclosed populations if the program is intense and sustained. A combination of small and large meshed designs should be used and emptied regularly, with trapping timed to coincide with peaks in AS crayfish activity in late September.

3.2.2.2 Electrofishing

Relatively few attempts have been made to control AS crayfish populations with electrofishing equipment, although this method has been employed successfully for sampling (Eversole & Foltz 1995) and in commercial harvesting (Huner 1988).

From the available literature a study by Sinclair & Ribbens (1999) is the only trial of electrofishing as a tool for AS crayfish control. Standard electrofishing equipment was used consisting of a bank-side generator, control box, a stationary braided copper cathode and a mobile anode. Unlike Westman *et al.* (1978), Sinclair and Ribbens (1999) found pulsed direct current to be superior to smooth. An electrofishing team of three moved in an upstream direction, with the operator stunning AS crayfish and catching them in a banner net. This removal method is identical to that commonly used in surveys of juvenile salmonids. Sections of stream were electrofished in three successive surveys and the number and length of AS crayfish caught after each run was recorded. This process was repeated a day later in each section to quantify the population not removed during the previous days survey.

Significant numbers of AS crayfish were removed from all sites, ranging in length from 5—9mm to 120–124mm. Frequency of capture reduced with AS crayfish size, a pattern that reflects the expected size distribution of the population. The efficiency of capture could not be estimated as after successive runs reductions in catches were insufficient to allow Zippin (1958) estimates of the total catch able population. Sinclair & Ribbens (1999), suggest that the unpredictable pattern of catch in repeated electrofishing runs may be due to the use of available refuges by the AS crayfish. Following each run, some individuals may have been disturbed from these refuges, thus making them vulnerable to capture in following runs and resulting in a low rate of catch depletion. Between 24% and 35% of AS crayfish captured at each site over two days were caught on the second day, demonstrating AS crayfish had not been completely removed from any section after three electrofishing runs.

Electrofishing creates an electric field in water to which fish will respond by some form of forced swimming and/or immobilisation, (SFCC 2001). If it were assumed that AS crayfish respond to electric fields in a similar way to fish, it would be expected that electrofishing might immobilize a percentage of individuals. AS crayfish typically find refuge in gaps between boulders or burrows. Immobilized crayfish may therefore be unable to leave these refuges. It is also possible that electric fields cause AS crayfish to retreat further into their refuge, a response recorded in eels (Environment Agency 1998). Electrofishing may therefore be a method that has the potential to catch a relatively low percentage of the total population.

Although the use of electrofishing to eliminate AS crayfish populations appears impractical, it remains a potentially useful method for reducing overall population size. However, stunning and capturing AS crayfish is impractical in deep water and electrofishing is accepted as method suitable only for clear, shallow water (Westman *et al*. 1979; Sinclair & Ribbens (1999)). The range of sizes caught demonstrates this method is suitable for removing individuals from all age classes. The effectiveness in catching both sexes is unknown.

Although pulsed DC is generally more effective in capturing fish than smooth, instances of damage to captured fish may be higher (SFCC 2001). Therefore, the use of pulsed DC to remove AS crayfish from any water body carries a risk of mortality in the resident fish population.

Providing workers are trained to recognised standards and use the correct equipment, electrofishing is a relatively safe procedure. There are however Health and Safety issues associated with transporting equipment by foot over long distances and difficult terrain. The equipment is widely available, affordable (approximately £3000) and accepted as a survey tool in fisheries management.

Electrofishing is a method that is relatively affordable, safe and acceptable. It is also effective in removing large numbers of AS crayfish of all sizes. However, further trials are necessary for its effectiveness to be measured and its suitability for use on a large scale to be assessed.

3.2.2.3 Netting

Three types of net have been used: drag netting, seine and fyke.

Drag netting or trawling of the riverbed and bank has been attempted on the Rivers Gwash (Peay 2001) and Wreake (Sibley 2000). This is a modified form of kick sampling in which teams of four or five form a staggered line across the stream. Workers move upstream, disturbing the substrate and capturing the AS crayfish with large hand nets. This is repeated up to four times. Compared to the results of trapping, this form

of netting was found to be much more efficient in catching AS crayfish of <35mm carapace length (Sibley 2000). It was also suggested that this form of netting is best suited to shallow, narrow sites and was more productive in June/July than October/December.

The effectiveness of drag netting in reducing AS crayfish densities has not been reported but it is unlikely that this would be a useful method for eradication. The effort and cost involved is likely to make its use unacceptable at a large scale. Similarly the impacts on invertebrates, fry and the structure of the stream bed are likely to be both severe and unacceptable on a large scale.

The use of seine and fyke nets has also been reported (Holdich & Domaniewski 1995). It is suggested that these nets are more efficient than traps in catching juveniles and ovigerous females (Rogers 1996) but they involve greater costs and manpower (Holdich *et al*. 1999). Additionally the use of seine nets will be limited where underwater obstructions exist, these areas are likely to be important crayfish habitat. Although fyke nets can be utilised in most places care must be taken regarding accidental catching of otters.

3.2.3 Biological control

3.2.3.1 Predatory fish

Although AS crayfish have many predators, Holdich *et al*. (1999) suggest that only fish are viable for use as a biological control. No attempts to introduce predatory fish with the aim of reducing or eradicating a population of AS crayfish have been reported. However, there is considerable evidence that fish may be extremely effective in reducing the size of AS crayfish populations.

Holdich *op.cit* reviewed a range of papers relating to the interaction between predatory fish and AS crayfish species, including *P. leniusculus*. They concluded that the majority of studies indicate predatory fish reduce AS crayfish populations and consume a high percentage of AS crayfish production. Svardson (1972) and Westman (1991) demonstrated that the absence of fish resulted in substantially higher AS crayfish numbers. In addition, Furst (1977) suggested that fish predation was the most important factor in limiting the establishment of new AS crayfish populations in Swedish lakes.

There are some cases where despite a high density of fish, AS crayfish populations remain high. For example, the signal crayfish population within an English lake actually increased, even though significant numbers of brown trout *Salmo trutta*, rainbow trout *Oncorhynchus mykiss*, perch *Perca fluviatilis* and carp *Cyprinus carpio* were present (Holdich & Domaniewski 1995). This is despite the fact that there are records of perch (Blake & Hart 1993), brown trout (Byrne *et al*. 1999) and carp (Maitland & Campbell 1992) feeding on AS crayfish species.

The species most likely to be effective in controlling AS crayfish whilst causing limited damage to other fauna is the European eel *Anguilla anguilla*. There are several accounts of eels predating heavily on AS crayfish in the wild (Svardson 1972; Furst 1977). In addition, Holdich *et al*. (1999) relate an account of AS crayfish farmers in Britain losing much of their stocks to eels. Eels are most active at night when crayfish activity is reportedly greatest (Blake & Hart 1993) and they are likely to be the most effective species at removing AS crayfish from their refuges. Other advantages are that eels can survive in a variety of aquatic habitats, they are already present in many water bodies throughout the UK and they do not breed in freshwater.

Conflicting opinions over the effect of predatory fish on AS crayfish populations, may be explained by the different habitat types and species studied. The availability of refuges varies within and between water bodies and has been demonstrated to be an important factor in AS crayfish survival (Saiki & Tash 1979; Blake & Hart 1993). It is reasonable to assume that the degree to which AS crayfish are predated upon also depends on both the species of crayfish and the species of fish present. The life stage and therefore size of both predator and prey will also influence levels of predation. Although many species of fish are likely to feed on AS crayfish of a suitable size, pike *Esox lucius*, perch and eels appear to feed most aggressively. Behavioural aspects of the species studied may also influence predation success. AS crayfish are reported to alter their behaviour in response to visual and chemical detection of predatory fish (Blake & Hart 1993) and perch and eels have markedly different feeding patterns (Blake & Hart 1995). There are also no guarantees that introduced fish will remain in the area intended and concerns over a low residence time was one of the reasons why a trial of eel and chub *Leuciscus cephalus* introductions to the River Gwash did not take place (Peay 2001).

The history of biological controls is littered with examples of species that are released in order to control a pest but end up becoming a problem themselves. The main danger posed by stocking fish is that they may compete with or predate upon the resident fauna. In addition, they may introduce diseases such as crayfish plague. Fish should undergo health checks before they are introduced and sourced from catchments free from crayfish plague. Efforts must be made to prevent the spread of crayfish plague, even in catchments where White Clawed crayfish are absent. This is because infected AS crayfish populations act as a reservoir of the disease and may be a source of further outbreaks if they increase their range. In addition, authorities must be satisfied that any impacts arising from introducing fish are justified by the threats posed by the presence of AS crayfish. It is possible that only fish species already present in the catchment may be permitted for release. There may also be considerable resistance from anglers concerned about the impact of predators on resident fish populations. Consideration would also have to be made to relevant legislation in particular the Conservation of native freshwater fish stocks: The prohibition of keeping or release of live fish (specified species) (Scotland) Order 2003.

The cost and effort related to stocking predatory fish is difficult to assess as this depends upon stocking levels and commercial availability of the desired species.

There is a significant body of evidence to suggest introducing predatory fish may be useful in controlling AS crayfish populations. However, due to lack of research in this area a cautious approach is very strongly advised. The most suitable fish would appear be the European eel, which is known to feed on crayfish. The most effective size and density of eels are unknown and further research is needed to determine the most effective stocking strategy. However the risks associated with field research are low as increased eel densities will not be permanent and the species is widely distributed throughout UK and Europe.

3.2.3.2 Disease

Crayfish suffer from a variety of diseases, some of which could be useful for their control. However, no diseases of AS crayfish cause 100% mortality. The use of the bacteria *Bacillus thuringiensis* or the fungi *Aphanomyces astaci* (the cause of crayfish plague) has been suggested (Holdich *et al.* 1999). However, strains would have to be developed that are highly effective and specific to AS crayfish before their use could be considered. Such developments are not expected in the near future.

3.2.4 Chemicals

Two groups of chemicals may be useful for the control of AS crayfish: biocides and pheromones.

3.2.4.1 Biocides

A wide range of chemicals have the potential to be used as a crayfish poison. However, many of these are indiscriminate and would pose a significant danger to resident biota and human health. As a result of these dangers, few field trials have taken place in Europe (Holdich *et al*. 1999), with the majority of researchers testing biocides in the laboratory.

Trials of poisoning with common chemicals have identified two approaches likely to work in the field (Peay 2001). Increasing pH to 12 or higher using sodium hydroxide and deoxygenating the water using sodium sulphite or sucrose addition are both effective. It is suggested that the following process that combines these approaches may increase effectiveness. Deoxygenate, increase pH, neutralise and aerate. This will clearly cause massive damage to the aquatic ecosystem and is not recommended for running water. The costs of these methods are likely to be relatively low, with minimal effort needed compared to manual techniques.

Other biocides such as organochlorine, organophosphate and pyrethroid insecticides are all as capable of killing crayfish (Holdich *et al*. 1999). However, due to their direct environmental impacts and the potential for bioaccumulation, Government agencies and conservation groups may raise significant objections. Holdich (1999) suggests that pyrethroids would have the least environmental impact, although other crustacean populations would be severely damaged.

Both surfactants (Holdich *et al*. 1999) and rotenone (Peay 2001) are unlikely to be effective in controlling populations of AS crayfish in the field.

Some biocides clearly have potential to be useful, particularly in closed systems. However, the protection afforded to crayfish by burrows and the probable impacts on flora and fauna make it unlikely that a suitable biocide will be available in the near future. In addition, AS crayfish may respond to toxic conditions by leaving the water (Peay 2001) and may therefore return at a later date.

3.2.4.2 Pheromones

The use of sexual attractants to enhance trapping success is widely used in insect control (Holdich *et al*. 1999) and has great potential for use with crustaceans. Sexual or territorial pheromones and repellents could be used to encourage crayfish into areas where trapping is more effective (Rodgers & Holdich 1998). The use of sexual pheromones to enhance trapping success has recently been investigated by Paul Stebbing (Newcastle University). Early reports suggest that female crayfish pheromones are effective, attracting males into traps (Brown 2002; Kempster 2002). Although research into this technique is in its early stages, it is likely that both attractants and repellents will be useful tools for crayfish management in the future.

The use of chemical signals in this manner is considered to be environmentally friendly (Rodgers & Holdich 1998).

3.2.5 Physical

3.2.5.1 Habitat destruction

Habitat destruction is designed to remove all potential AS crayfish refuges (Peay 2001), making them much more vulnerable to other control methods and natural predation. This is considered to be impractical in rivers but has been attempted in a small pond (Peay 2001). Following drainage, the substrate was excavated and removed from the site. Subsequent monitoring recorded that AS crayfish were still present. It is unlikely that habitat destruction can ever be successful in eliminating AS crayfish, as they are likely to recolonise from riparian refuges and local water bodies. Such habitat destruction is likely to be costly and cause unacceptable damage to the local environment.

3.2.5.2 De-watering

There are very few references to support the view that draining of lakes or sections of a stream in order to remove the resident crayfish is effective. Holdich & Reeve (1991) report that draining of a farm pond and removing the resident crayfish was ineffective, with AS crayfish surviving the drain-down in burrows and then restoring the population to its former level once levels are restored. The damming of a section of the River Ure was considered as a control method, reducing water levels to allow removal of AS crayfish (Rodgers & Loveridge 2000). However, the construction of the dam was considered to be too dangerous as well as being very expensive (£40–50,000).

Weirs, electric fences and acoustic bubble screens have all been suggested as methods for preventing the spread of AS crayfish along a waterway. However, these barriers will ultimately be breached due to the ability of AS crayfish to navigate around these by moving across land (Bubb *et al.* 2001).

3.2.5.3 Catch-pits

Rodgers and Loveridge 2000 describe the development of an interceptor (catch-pit) at the outlet of a lake known to contain AS crayfish. Problems were experienced with the design of the outlet pipe and blockages in the interception chamber, allowing AS crayfish to pass through. It is anticipated that further development will prevent such escapes and this technique may be of considerable use in the future.

3.3 Discussion

The aim of this report was to review methods suitable for the containment and small-scale eradication of AS crayfish. A successful method would therefore deliver a temporary or permanent reduction in the size of a AS crayfish population, or its complete removal. During field trials, no methods have been proven to be fully successful in this respect. However, these trials have not been exhaustive and crayfish control may be possible in different situations or using different approaches.

Of the methods currently available for use in the field, trapping and electrofishing appear to be the most effective and acceptable options. Both sets of equipment are affordable and readily available, although some traps must be modified with smaller mesh and smaller entrance apertures. The environmental impacts of both methods are likely to be minimal but damage to aquatic mammal and fish populations may occur and should be closely monitored. Unlike electrofishing, trapping is biased towards male AS crayfish and

also towards larger individuals, even when modified traps are used. However, trapping may be more suitable for remote locations and in turbid or deep water. Both methods have been used to remove large numbers of AS crayfish but neither has been proven to be effective in total removal. Although reductions in catch over time are reported, there is no published evidence available to show that populations as a whole have ever been significantly reduced. A sustained and intensive program of electrofishing or trapping is the strategy most likely to achieve this aim.

Of the remaining options, the introduction of predatory fish has the greatest potential to be useful in managing AS crayfish populations. However, due to the lack of research in this area a cautious approach is appropriate and it is likely that this approach will not be acceptable in Scottish waters. The European eel appears the most suitable species for trials at present as it is already native to almost all European Freshwaters, feeds heavily on crayfish and does not breed in freshwater. More research is needed to determine whether this approach is possible within Scotland and to develop an effective stocking strategy.

Drag netting is effective in removing large numbers of AS crayfish of all sizes. However, it is also intensive compared to other methods, is unlikely to remove the whole population and may cause high levels of habitat damage. Fyke and seine nets are considered to be unsuitable due to their impacts on other aquatic fauna.

Physical methods such as de-watering and habitat destruction have been shown to be ineffective, costly and in some cases may pose a risk to the Health and Safety of those involved. However, the development of effective interceptor chambers (catch-pits) may be a useful method for preventing further escapes from still waters.

Some biocides clearly have the potential to be useful for control or eradication, particularly in closed systems. Peay (2001) concludes that chemical control is the only method likely to be effective in controlling or eradicating AS crayfish. However, the protection afforded to AS crayfish by their burrows and the probable impacts on flora and fauna make it unlikely that a suitable biocide will be available in the near future.

For several of the aspects considered, comparisons between methods can be difficult. Economies of scale make it difficult to determine which method is the least expensive, without first knowing the size range and spatial distribution of the AS crayfish population in question. Accurate estimates of density and population size are not possible as methodologies are imprecise and these require substantial development (Holdich *et al*. 1999; Peay 2001). This makes comparing the effectiveness of each method in reducing AS crayfish population size impossible. It also suggests that trials of some methods may have been successful in controlling AS crayfish populations but reductions were simply not detected.

A bias towards large AS crayfish was observed with trapping and is likely to occur to some degree with electrofishing and predation. This is probably due to the behaviour of small AS crayfish whose size makes them particularly vulnerable to predation and therefore reluctant to venture from their refuges. However, such a bias is not necessarily a problem as long as a high percentage of adults are removed each year. If the number of adults is low enough, the level of reproduction will be insufficient to maintain a large population size.

One of the main concerns expressed by many authors is the possibility that medium levels of AS crayfish removal may result in increased growth rates and reproductive success due to reduced intra-specific

competition and predation. Without more research into the population dynamics of AS crayfish it is difficult to estimate the level of removal, above which the population size will fall (Smith & Wright 2000). This level of removal is likely to be found by empirical study.

No single method will be appropriate for all situations and Holdich *et al.* (1999) suggest each nuisance population of AS crayfish requires a method designed to address its individual circumstances. A combined strategy may overcome some of the limitations of individual methods and several authors recommend that this approach should be explored further (Bills & Marking 1988; Holdich *et al.* 1999).

In order to develop an effective method of localised control, it is vital to identify the level of removal needed to reduce AS crayfish densities. It is also important to be able to assess how fast densities recover following programs of removal. In order to do this, a method of accurately estimating AS crayfish densities is required. The major flaw with previous attempts to do this is that small AS crayfish were under represented. One approach that may increase accuracy is the use of two methods, sampling different size ranges. Exhaustive runs of electrofishing or drag netting are likely to deliver a representative sample of larger AS crayfish and are practical to carry-out over relatively small areas. In order to gain a representative sample of juvenile AS crayfish, the enclosure method developed by Byrne *et al.* (1999) could be employed. This involves repeatedly sampling and sorting material from the streambed, using a plastic cylindrical enclosure.

There is a danger that trapping AS crayfish will become popular amongst the public and encourage both illegal and accidental introductions. It is clear that the release of AS crayfish in Scotland is illegal and that keeping them is prohibited unless a license is obtained from Scottish Ministers (hotels, restaurants and markets are exempt).

3.4 Conclusions

Modified trapping, electrofishing and the possible introduction of European eels have been identified as the most effective and acceptable methods currently available for controlling AS crayfish. Chemical signals and biocides both have great potential for use in the future and research in these areas should be continually reviewed.

It is vital that an accurate survey method is developed to allow the effectiveness of any program of AS crayfish removal to be measured.

4 REVIEW OF APPROACHES AND METHODS USED ELSEWHERE IN SCOTLAND TO CONTROL AS CRAYFISH

4.1 Introduction

A visit to the River Clyde was undertaken by the GFT on the 22nd November 2002 to meet Willie Yeomans, senior biologist with the Clyde Foundation and members the United Clyde Angling Club who are involved in trapping AS crayfish on the upper reaches of the River Clyde. An intensive trapping programme is being carried out over a reasonable period of time to try and halt the spread of AS crayfish on the upper Clyde catchment. This work is funded by SNH.

The visit by GFT was arranged in order to meet and set up links with those involved in trapping AS crayfish in Scotland and to learn more about the AS crayfish problem on the River Clyde. A day was spent in the field to gain additional information on trapping methods and techniques successfully employed.

The information within this section is related to the AS crayfish situation within the River Clyde and is derived from personal communications received on the day of visit.

4.2 Extent of AS Crayfish distribution on the upper reaches of the River Clyde

In the upper Clyde, AS crayfish have established themselves in areas where previously there used to be high juvenile trout densities. It was suggested that numbers of juvenile trout have decreased in the upper Clyde and there is only a low density of large trout remaining. There used to be a well-established fishery on the upper Clyde for trout and grayling but since the AS crayfish populations have become greater the sport has declined.

4.3 Trapping methods

Pipe traps have been utilised to some extent on the Clyde but have been found to be ineffective. Bucket traps have also been tested and were found to be labour intensive because they had to be dug into the substrate. Trappers on the Clyde use standard cylinder crayfish traps. Cylinder traps were found to require weights when placed in deeper pools. When the GFT suggested the method of modifying the traps with small mesh wire to reduce the mesh size and trap entrance size, the individuals on the Clyde felt that this may be quite an effective method to allow only smaller AS crayfish to enter traps.

On the upper Clyde, 100 traps are placed out. Their method of trapping commences by trapping heavily at the bottom section of an area of river and then moving upstream slowly, leaving a few traps behind. If any deeper areas are present, these continue to be trapped. On the Clyde, traps have been moved upstream for 6.5km since trapping started. They find that the method of moving slowly upstream seems to work effectively.

Trappers on the Clyde place traps where the water flow creates back eddies that are around 1m, or below sand banks and collapsed sods of earth. They always try to trap the deep side of the river, but not if there

is a spate. They trap the shallow side in winter with long bank ties so that traps are washed ashore rather than being lost.

Cable ties are used to stop traps opening and to ascertain if anyone has broken into the trap.

4.4 Trapping times

Trappers on the Clyde have found that during the months of August, September and October more female AS crayfish than male AS crayfish are caught. This has happened for three years in a row. It is believed that just before and just after the females have become 'berried' (eggs have developed and they are attached to the females swimmerettes), and just after the females have released their young, there is a large influx of females entering the traps.

They have found that December and January yield the lowest numbers of trapped AS crayfish. Numbers have been seen to go from hundreds caught per month in the summer to 70 or 80 a month during the winter. Even with this in mind, they feel it is still worth trapping during the winter months. The people on the Clyde feel that the best time to trap is during the months of June, July and early August. These are the times when most AS crayfish are caught.

4.5 Bait types

Trappers have found that AS crayfish sense food very quickly and have found that rabbit, game, pheasants, trout and salmon are good bait for attracting AS crayfish into traps. Generally they found trout pellets ineffective, and are only really suitable for use in summer when the water is warmer. Similarly, oily fish was ineffective as bait for AS crayfish. Trappers on the Clyde have found that rainbow trout and dead AS crayfish tails are especially effective for attracting AS crayfish into traps.

A new baiting strategy that the trappers on the Clyde might try is the method of making holes in tins of dog food. These tins are then put inside a trap so the very small AS crayfish go into the tin and hopefully will not come out. It was said they may also try and fill a cylinder trap full with straw and weed containing bait in order to catch small AS crayfish and prevent larger ones from entering. On the Clyde they feel that smaller AS crayfish will not enter a trap if large ones are already inside because they are considered prey to larger AS crayfish.

On the Clyde, the trappers find it is better to use the bait boxes within traps rather than using bait pins.

4.6 Trapping success

Trappers estimate that around 30,000 AS crayfish have been captured in their traps on the upper Clyde since they started trapping.

Substantial numbers of AS crayfish are captured on the Clyde annually, with 15,254 AS crayfish caught between 01/08/01 and 15/11/02 (see **Table 1**).

Continuous trapping has taken out the larger AS crayfish in the upper reaches in the Clyde. Of the large AS crayfish captured, roughly 40% of these were female and 60% were male. It has apparently taken three years of continuous trapping to reduce the size of AS crayfish caught.

On the Clyde AS crayfish reach sexual maturity at a younger age (smaller size) because all the larger, older, individuals have been trapped out. The trappers feel that the remaining population is trying to sustain itself. They also feel that the best scenario would be to capture them before they reach sexual maturity.

Table 1 Recorded numbers and sex of AS crayfish captured during trapping work on the upper Clyde between 1/8/01–15/11/02

	MALES	FEMALES	MONTHLY TOTAL
August 2001	710	521	1231
September 2001	1560	1176	2736
October 2001	1059	289	1348
November 2001	638	503	1141
December 2001	433	258	691
January 2002	90	115	205
February 2002	70	20	90
March 2002	245	86	331
April 2002	347	90	437
May 2002	332	79	411
June 2002	161	41	202
July 2002	544	426	970
TOTAL FOR YEAR	**6189**	**3604**	**9793**
August 2002	692	800	1492
September 2002	869	1236	2105
October 2002	890	346	1236
November 2002 (up to 15/11/02)	470	158	628
TOTAL FROM 01/08/02 – 15/11/02	**2921**	**2540**	**5461**
TOTALS	**9110**	**6144**	**15254**

4.7 Other attempted methods of AS crayfish control

In addition to the heavy trapping of the upper Clyde, over 30kg of 30cm long eels were introduced to the area. Eels were not present in this area previous to the introduction because of the impassable Falls of Clyde downstream of the AS crayfish infested area. It was not felt that this experiment had been a success, as the eels were never seen again.

4.8 AS crayfish information/biology and habits

Trappers on the Clyde suggest that AS crayfish are more active in the early morning in Scotland.

Trappers on the Clyde feel that male AS crayfish tend to establish a territory first, and only then do they let off pheromones to attract the females into that territory.

No one on the Clyde has ever seen an AS crayfish travel a distance over wet grass. Interestingly, they have seen them create burrows of up to 1m long (into the banksides) above the water level. The burrows bend back into the banking at a downward angle. To the untrained eye, these burrows look like a mouse hole in the bankside. AS crayfish tend to burrow in the Clyde because there are few large rocks to hide under on the riverbed. Generally it was felt that AS crayfish are more successful if they do not have to burrow into banksides.

Three different ways of AS crayfish burrowing have been observed on the upper Clyde:

i. AS crayfish may use their tail as a digger to remove earth from banksides to create a burrow,

ii. they snip small chunks of earth of the bankside using their large claws, or

iii. they actually use their large claws for digging into the bankside. It has been found that the AS crayfish dig deeper holes in areas with a faster current.

Therefore, trappers on the Clyde feel there is a better chance of controlling the AS crayfish population if you are working in an area with a slow current.

4.9 Disease

AS crayfish can carry crayfish plague. Evidence from the Clyde suggests that this melanises their skin but does not kill them. The plague kills all native crayfish but not AS crayfish, however it will degrade their carapace and creates large holes, but they survive. Claws regenerate if they fall off and even if they do, the AS crayfish can feed with other smaller pincers.

Trappers on the Clyde feel that if the crayfish plague can be mutated then this would be the best way of killing AS crayfish and eradicating them.

5 QUESTIONNAIRE ANSWER BREAKDOWN

Within phase 1 of the project a questionnaire was produced regarding AS crayfish within the Ken/Dee system (see **Appendix 1**). The purpose of the questionnaire was to gauge the level of public awareness of AS crayfish and aim to collect any information the public held and any additional records of AS crayfish distribution and abundance within the Ken/Dee. Within the questionnaire, the GFT also aimed to gauge the level of awareness of current Scottish legislation regarding AS crayfish.

One hundred and forty four questionnaires were distributed to known interest groups, for example SNH, SEPA, Dee Catchment Management Group and Loch Ken Management Group. Questionnaires were also distributed through the Dee DSFB and to individuals such as anglers, riparian landowners, farmers, owners/occupiers, a number of local catering establishments, Community Councillors etc. A further 100 questionnaires were left in key locations for people to collect eg fishing huts and fishing ticket outlets. Seventy two questionnaires were completed and returned.

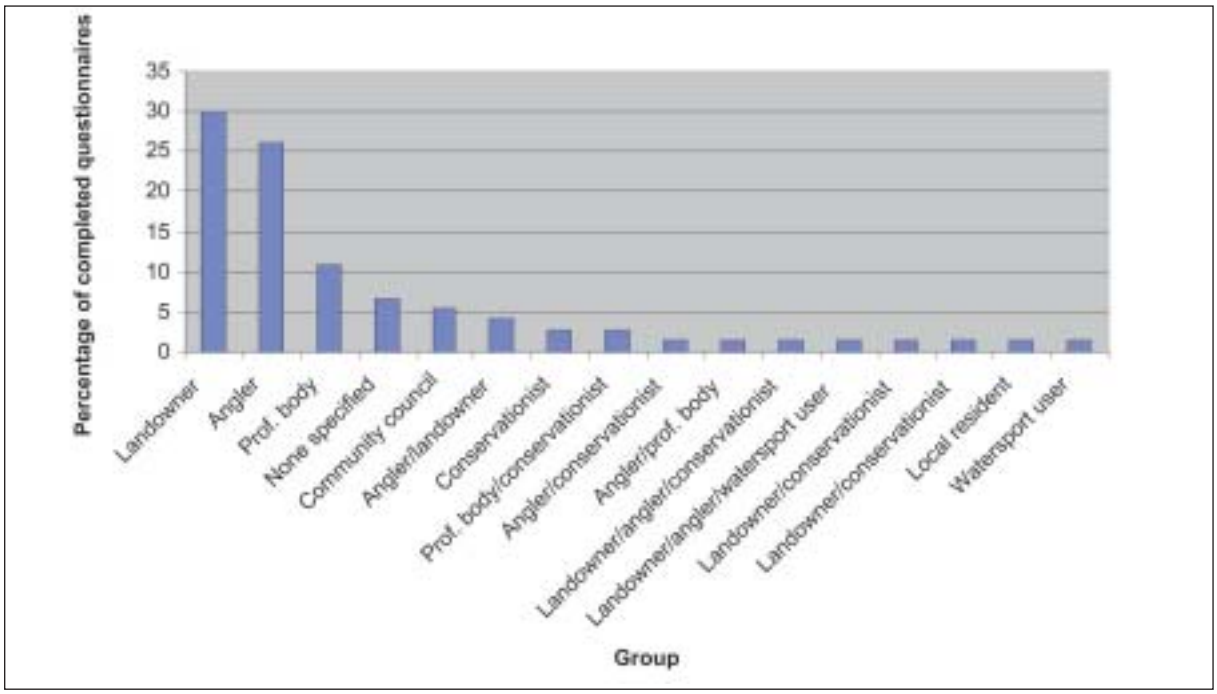
Ten main questions were included within the questionnaire. Results of the answers to each question and a summary of the breakdown are shown below.

5.1 Q1 – Please indicate which group you feel best describes yourself

This question was considered to be important in order to verify that information was being collected from individuals from a wide range of backgrounds.

Categories were listed for individuals to indicate which best described themselves (see **Table 2**). Several individuals classed themselves within two categories, for example, landowner and conservationist. Of the questionnaires, 30.1% of individuals classed themselves as landowners within the Ken/Dee area and 26% classed themselves as anglers. 11% said they were representing

Table 2 Classification of individuals who completed AS crayfish questionnaire



professional bodies, for example, SNH and SEPA. 6.8% of individuals did not select a named category nor did they specify an 'other' group. 1.4% of individuals classed themselves as watersport users on the Ken/Dee system. Community council members/representatives returned 5.5% of the returned questionnaires. 2.7% of individuals classed themselves as conservationists.

Individuals who classed themselves as landowner/angler, conservationist/professional body, landowner/watersport user, professional body/angler, angler/watersport user/landowner, landowner/angler/conservationist, angler/conservationist, landowner/conservationist and local resident completed the remaining 16.5% of questionnaires.

5.2 Q2a – Did you know that AS crayfish were present within the Ken/Dee system?

It was interesting to note that 77% of individuals expressed that they knew that AS crayfish were present within the Ken/Dee system. 23% said 'No' – they were unaware of the presence of AS crayfish prior to receiving the questionnaire.

Q2b – If yes (to Q2a) then when and how did you find out?

The majority of individuals found out relatively recently, mainly within the last four years, with the majority having found out within the last two years. An absolute timescale was not specified on nine questionnaires. Various explanations of how individuals found out were received. One individual answered that a rumour was heard at school some 30 years ago about the presence of AS crayfish within the Ken/Dee system. Many of those who classed themselves under the 'angler' category found out whilst angling. Many individuals found out through word of mouth, however it was interesting to note that 22% mentioned that they had found out via information/talks with either the Dee DSFB, GFT talks or Ken/Dee management group meetings.

5.3 Q3a – Do you feel the introduction of AS crayfish is a concern?

Once again, 77% expressed a concern about the introduction of AS crayfish to the Ken/Dee system. However, it did not always follow that a 'Yes' in answer to Q2a meant a 'Yes' in answer to Q3a. 19% of completed questionnaires stated 'No' concern and 7% did not answer or stated that they did not know if the introduction of AS crayfish was a concern.

Q3b – Why? (In reference to Q3a)

Many individuals wrote several lines on why they thought the introduction of AS crayfish was a concern or otherwise. 39.7% mentioned being concerned about AS crayfish preying on fish eggs, being in breeding grounds and fish spawning gravels. 50.5% expressed a concern regarding the impact to local biodiversity, flora and fauna, balance of the local ecosystem and ecology. 30.7% mentioned the fact that AS crayfish were an alien species and 3.6% mentioned that they are rapid breeders and invasive. 3.6% mentioned a concern regarding damage to habitats. 14.4% regarded the stripping of angler baits by AS crayfish a concern. Only one individual mentioned possible disease threats from the presence of AS crayfish. 18% did not know or did not elaborate.

5.4% thought that the presence of AS crayfish added to the biodiversity and provided a good source of food for fish. One individual could see no harm in the presence of AS crayfish within the Ken/Dee system.

Q3c – If 'Yes' to Q3a, then please say what you feel should be done to address your concern

Of those who answered 'Yes' to Q3a, 28.9% mentioned AS crayfish removal, with 21.6% mentioning eradication in particular. 34.3% mentioned the fact that the AS crayfish should be controlled or their spread to new areas prevented. Further research into the effects of the presence of AS crayfish, evaluation of management practices, and monitoring was mentioned on 14.4% questionnaires. 9% felt that trapping should be undertaken on the Ken/Dee system. 14.4% did not know enough to comment and a further 7.2% felt that the public awareness should be raised or that the public needed to be educated on the problems of AS crayfish. 5.4% declined to answer and one person felt that the presence of AS crayfish did not require drastic measures to be taken.

5.4 Q4a – Do you know where AS crayfish are present within the Ken/Dee system? If so please specify locations

40% stated that they did not know where AS crayfish were present on the Ken/Dee system and 60% stated that they were aware of areas where AS crayfish were present.

Of the 60%, 50.9% mentioned the presence of AS crayfish in the River Ken and 20.8% commented on their presence in the burns around New Galloway. Many individual burns were mentioned as having AS crayfish present, for example, the Achie Burn, Shirmers Burn, Garrouch Burn and 11.6% mentioned the Garple Burn in particular. Many of the individuals who classed themselves as 'anglers' in Q1 mentioned the presence of AS crayfish in various areas and bays around Loch Ken, for example, the west bank, Double Bridges, Boathouse Bay and Robin Hood Bay. One individual suggested that AS crayfish may be present in the Skyre Burn (near Gatehouse of Fleet). For a detailed area of distribution please see Section 6.

Q4b – How did you find out where they were present?

85.6% indicated that they had found out that AS crayfish were present within the Ken/Dee system via word of mouth. AS crayfish had been sighted by 41.7%, and a further 39.4% had discovered their presence whilst angling. Interestingly, 23.1% stated 'trapping' as the manner in which they found out, whether this was trapping first-hand or whether they had heard about trapping being undertaken was not clear. 13.9% heard about the presence of AS crayfish in the Ken/Dee system via the media.

5.5 Q5 – Have you ever captured AS crayfish from the Ken/Dee system or its streams? If yes, by what method?

In response to the first part of this question 59% said 'No', however 36% said 'Yes'. 5% of individuals declined to specify.

Of the 36% who said 'Yes', 65% had captured AS crayfish whilst angling, mainly in the area of the west bank of Loch Ken, Boathouse Bay and in the River Ken. 23% indicated that they had captured AS crayfish by hand. Most did not specify locations, however 7% mentioned Garroch Burn. 15% indicated that they had captured AS crayfish via trapping methods, but did not specify locations. One person had captured AS crayfish whilst cleaning out ditches and another individual had captured AS crayfish using electrofishing techniques.

5.6 Q6 – Are there any specific areas on the Ken/Dee system that you feel are particularly vulnerable to AS crayfish and if so, why?

15.28% mentioned spawning areas were at risk from the presence of AS crayfish. 2.78% mentioned that the rivers were at risk more so than the lochs. Conversely, many of those who considered themselves 'anglers' in Q1, thought that the loch systems were more at risk, naming many of the aforementioned bays. One individual considered the River Dee to be at risk, as they had not observed AS crayfish as being present there. Additionally, one individual indicated that designated areas such as nature reserves may be at risk from the presence of AS crayfish. One person felt that all Scottish rivers were at risk from AS crayfish.

5.7 Q7 – Do you know of any hotels/restaurants which presently have freshwater crayfish on the menu? If so, where?

In answer to this question, 47.22% did not know of anywhere selling crayfish on a menu and 8.33% declined to answer. However, 47.22% indicated two different hotels in the Ken/Dee area. One individual indicated 'Yes' they knew of somewhere with crayfish on the menu, but did not specify where.

5.8 Q8 – Do you know of any trapping/harvesting of AS crayfish in the Dee catchment taking place? If so, where?

51% of individuals did not know of any trapping or harvesting taking place within the Dee catchment. 26% mentioned that they were aware of trapping/harvesting taking place for/by hotels for sale on their menus. 4% of responses indicated that they knew of trapping/harvesting taking place for bait or food. It was interesting to note that one individual indicated that a reward was being offered to anyone who trapped AS crayfish in a particular area. Additionally, one individual mentioned that trapping was taking place to capture AS crayfish in order to sell them to the south. One individual indicated that trapping was being undertaken in the River Ken. The remaining individuals declined to answer this question.

5.9 Q9a – What do you think should be done with the AS crayfish present in the Ken/Dee system?

58.33% thought that AS crayfish should either be controlled or eradicated from the Ken/Dee system. 4.17% felt that the AS crayfish should be harvested, a further 4.17% thought that they should be controlled and harvested and a further 5.56% thought that they should be harvested and/or nothing be done. 4.17% specified the 'other' category and mentioned that research should be done and advice should be sought about AS crayfish spread in the Ken/Dee system. 6.94% did not know what should be done and nine individuals declined to answer.

Q9b – Please elaborate further (on answer to Q9a)

Many differing explanations were received in answer to this question. Many individuals felt that although eradication was desirable, control might be the only feasible answer to the spread of AS crayfish. It was interesting to note that a few individuals felt that due to the AS crayfish presence they were now part of the food chain, caused no harm, they were a vegetarian species and were a source of food for trout and salmon. Additionally, a small percentage thought that they were now a natural resource and should be utilised for profit. Several individuals felt strongly that they were an alien species and were a very serious threat to the flora and fauna of the area.

5.10 Q10a – Are you aware of any legislation regarding crayfish in Scotland?

77% indicated that they were unaware of any legislation regarding crayfish in Scotland. 21% felt that they were aware of some legislation to a limited extent. 2% did not specify.

Q10b – If yes (to Q10a), please elaborate

79.36% indicated a limited knowledge of some current legislation regarding crayfish. 39.68% mentioned that AS crayfish were an alien species and that it was illegal to introduce them or move them alive.

Q10c – Do you feel that the legislation should be strengthened or relaxed? Please mention any ideas that you have

25% of individuals felt that current legislation regarding AS crayfish should be strengthened. 8% felt that they required more information before commenting and a further 8% specified that they did not know. 3% of individuals thought that the existing legislation should be relaxed or abandoned. The remaining individuals declined to answer.

5.11 Summary

5.11.1 Generally, a large percentage of individuals who completed the questionnaire were aware of the presence of AS crayfish within the Ken/Dee system.

5.11.2 Of those who knew AS crayfish were present, a large number indicated that their presence was harmful and damaging to the natural flora and fauna found in the Ken/Dee area.

5.11.3 Many areas containing populations of AS crayfish were mentioned in the responses, such as tributaries around New Galloway, Garple Burn and Loch Ken. Individuals usually found out AS crayfish were present via word of mouth, angling or sightings.

5.11.4 In general, it appeared there was a strong feeling throughout the responses that AS crayfish should be controlled or eradicated from the Ken/Dee system.

5.11.5 A large number of individuals specified that they knew/were aware of certain hotels/restaurants that had crayfish on the menu.

5.11.6 A surprising number of responses indicated that they knew of harvesting or trapping that was being undertaken within the Ken/Dee system. It may be the case that this practice is common knowledge, if it was openly being undertaken by hotels or restaurants for addition to a menu.

5.11.7 A small number of individuals indicated that they knew something of Scottish legislation regarding crayfish, however awareness of specific orders was limited.

5.11.8 From the responses, a general feeling was observed that current legislation should be strengthened. Many felt they did not know or required more information to comment.

5.11.9 Several individuals asked for more information regarding AS crayfish as little information was available for them to comment satisfactorily within the questionnaire. Additionally, many of the concerned individuals would like to be kept up to date on the progress of any studies on AS crayfish that are taking place on the Ken/Dee.

5.11.10 From the responses on the questionnaires, it appears that in general, the public are somewhat concerned about the presence of AS crayfish within the Ken/Dee system. At the moment, although many are aware of the existence of AS crayfish, it appears that they are unsure as to what measures they can take to help remedy the situation. The GFT feel that if more information on AS crayfish and the problems associated with their presence was readily available, individuals may be able to take a more active role in helping to prevent their spread to new areas.

6 AS CRAYFISH DISTRIBUTION IN GALLOWAY

The known distribution of AS crayfish in Galloway includes parts of two river catchments, the Kirkcudbrightshire Dee and the Skyre Burn (see **Map 1**).

6.1 Kirkcudbrightshire Dee catchment

The first confirmed records of AS crayfish in Galloway were recorded in 1996 when electrofishing surveys on the Kirkcudbrightshire Dee catchment found a reproducing population in the Garple Burn and Achie Burn (West Galloway Fisheries Trust, 1996). A further detailed survey of distribution, completed in 1999, found AS crayfish present in the Garple Burn, Achie Burn, Glenlee Burn, 9.5km of the main river (Water of Ken) from St Johns Town of Dalry to New Galloway and had probably reached Loch Ken (Sinclair & Ribbens, 1999). The results from questionnaire (see **Section 5**) and field work undertaken by the GFT since 1999 have confirmed that the previously described distribution continues. In addition it has been suggested that Shirmers Burn, Coom Burn, ditches at the disused Kenmure Fish Farm and Viewfield Curling Pond all have AS crayfish present. All of these sites are in the vicinity of previously recorded populations.

There are no records from GFT electrofishing surveys or through the questionnaire of AS crayfish presence above Earlstoun Dam. This hydroelectric dam would appear to be stopping the expansion of the population upstream at present.

It is apparent that Loch Ken now supports an AS crayfish population. A number of questionnaires returned by anglers indicated that AS crayfish regularly take static baits when fishing the west side of Loch Ken. Records were provided for most of the bays popular with angling down to Green Isle (NX662727). The upper 5km of the Loch down to Green Isle appears to support a healthy AS crayfish population. Further downstream few reports have been made of AS crayfish presence with isolated incidences reported around Boreland of Parton (NX689700). No records have been found to suggest AS crayfish presence in the lower 6.5km of Loch Ken or in the lower 18km of the River Dee between Loch Ken and the estuary. Regular visual surveys and kick samples are undertaken in the lower river at Dildawn (NX725594) and have not found presence of AS crayfish (personal communication, Ewing).

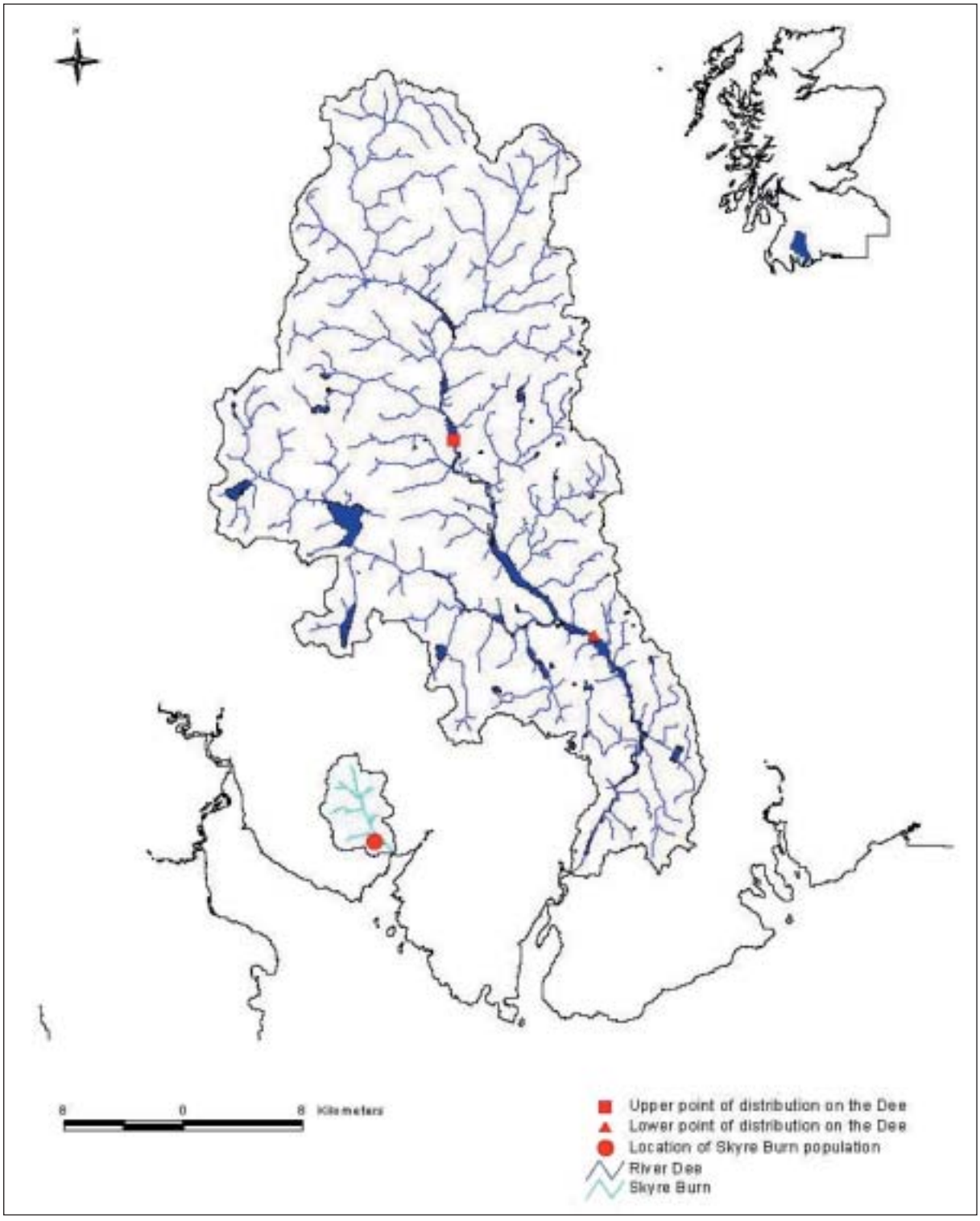
It is not apparent whether the lack of AS crayfish in the south section of Loch Ken is due to the presence of unsuitable habitat or simply that the population is still expanding into this area. The River Dee below Loch Ken appears to provide suitable habitat to support an AS crayfish population.

The information collected would suggest that within the Kirkcudbrightshire Dee catchment that the AS crayfish population is distributed from Earlstoun Dam (NX615821) down to Boreland of Parton (NX689700) a length of approximately 15km. All major tributaries within this section also have reported AS crayfish populations.

6.2 Skyre Burn catchment

This study has confirmed the presence of a previously unrecorded AS crayfish population in the Skyre Burn (outflow NX572546), Galloway. This small catchment, near Gatehouse of Fleet, was reported to the GFT as having an AS crayfish population for a number of years, with local children collecting buckets of them every summer. The GFT undertook a visual and limited trapping survey across the catchment.

Map 1 Location of known AS crayfish populations in the Dee and Skyre Burn catchments, South West Scotland



Even though the survey work was undertaken during a time of year when AS crayfish presence and activity would be minimal, an assessment was made of distribution within the Skyre Burn catchment.

It would appear that the population is abundant in the Lagganmullen Burn (NX568553), a tributary of the Skyre Burn. This watercourse is limited in size, only approximately 1km in length and 1m wide at its widest point. A set of vertical falls being approximately 1m high is present at the outflow of the burn. The burn is linked to a number of man-made ponds of varying sizes. It is likely that the initial introduction to the Skyre Burn catchment was through this sub-catchment. The ponds offer perfect habitat for AS crayfish, with a number of them having boulder islands, which provide good cover. The landowner stated that large numbers of AS crayfish could be seen in the ponds during the summer and that heavy grazing of aquatic vegetation resulted (personal communication, Rowsell). During road maintenance and ditch cleaning AS crayfish had also been reported in removed substrate.

Survey work undertaken in the Skyre Burn did not find any AS crayfish upstream of the Lagganmullen Burn outflow (NX568553). Downstream and in the immediate vicinity of the Lagganmullen Burn outflow a very low AS crayfish population was found, which did not appear to contain any of the younger (1–2 year old) age classes. This would suggest that the lower Skyre Burn may not provide suitable habitat due to its gradient and substrate. There are a number of sets of falls in the lower catchment, which may also hinder the movement of the AS crayfish. It would appear that the AS crayfish population in the main Skyre Burn is limited in size and distribution. The Lagganmullen Burn population is healthy and probably supplying the recruitment for the lower Skyre Burn.

6.3 Other populations in Galloway

During the course of this study it has been suggested by a number of individuals that certain people involved in the trade of selling AS crayfish may have introduced AS crayfish to a number of small ponds for possible future harvesting. Although the GFT have not been able to confirm this or get possible locations, the information sources were reputable and in the opinion of GFT should be taken seriously. Further suggestions of a pond population used for personal consumption between Dundrennan and Auchencairn, which is to the east of the Dee catchment, has not been confirmed or located. This report is of particular concern as it is out with the catchments of the previously recorded populations.

7 DEVELOPMENT OF CONTAINMENT AND SMALL SCALE ERADICATION METHODS

The literature review (Section 3) states that no method of control has been successful in delivering a permanent reduction or eradication of any AS crayfish populations in the UK. Although this appears disheartening it is important to remember that in Scotland the situation is different than that in England. There are still relatively few populations known to be established north of the Border which in most cases are still in early stage of infestation. These known populations are still relatively localised within defined geographical areas and it is not known how suitable the local environments are to support long-term populations.

The Galloway populations are apparently expanding and not believed to have stabilised. The main concerns are the continued expansion of these populations within the affected catchments and the establishment of breeding populations in new catchments. Although literature suggests that AS crayfish will travel overland, the known populations in Scotland all appear to have originated from deliberate introductions or have escaped from holding facilities. While it is imperative to ensure that the possible deliberate or accidental introduction of AS crayfish is halted it is important that work is focused on limiting the spread of the two known populations in the region, in particular into areas highlighted as sensitive for economic or biodiversity reasons.

It is important to appreciate that, as suggested in the literature review, that it may not be practical or possible to eradicate the established AS crayfish populations on the Skyre Burn and Kirkcudbrightshire Dee catchments.

7.1 Possible methods

The literature review and examination of the work undertaken on the Clyde have suggested a number of possible control techniques. These include trapping using modified traps, electrofishing and the introduction of predatory fish. In this report the possible poisoning of a minor watercourse is considered.

Suggested control and eradication programmes are detailed below. This includes detailed plans for each of the known populations and more general strategies to discourage the movement and introduction of AS crayfish.

7.1.1 Kirkcudbrightshire Dee catchment

The Kirkcudbrightshire Dee AS crayfish population was the first recorded in Scotland in 1995. This population was monitored in 1996 (West Galloway Fisheries Trust 1996), 1999 (Sinclair & Ribbens 1999) and 2003 (see Section 6). These studies have suggested that a gradual expansion from the initial introduction sites (which are believed to be the Achie Burn and Garple Burn) to its present range has occurred. It is considered important to control the further spread of this population of AS crayfish.

The upstream spread of the population appears to have been halted by the Earlstoun Dam (NX614824). Although a fish pass exists at this site, it is not considered likely that AS crayfish will be able to ascend this facility.

The AS crayfish population is abundant in the Water of Ken and its main associated tributaries (Garple Burn, Achie Burn, Glenlee Burn, Coom Burn) between Earlstoun Dam and Loch Ken. Electrofishing undertaken by the GFT has suggested that these tributaries provides important habitat for juvenile Atlantic salmon, brown trout, minnows and stone loach. Atlantic salmon are a Local Biodiversity Action Plan (LBAP) species. No additional biodiversity concerns have been raised in this area through the questionnaires or by relevant Government agencies.

It is widely appreciated that AS crayfish can cause devastating ecological damage through grazing, predation and habitat modification (Maitland *et al*. 2001) and thus it would be desirable to undertake a control programme in this area. No suitable methods exist, at present, which would be expected to result in eradication of the population. The only practical method of control would be the use of modified traps in suitable areas. The focus of trapping should be in the Water of Ken and the key tributaries. Key limiting factors in any trapping programme will be the flow of the main river, controlled by Scottish Power hydro activity, and whether suitable depths exist in the tributaries for traps to be effective. A study was undertaken to assess these concerns (see Section 8).

Within Loch Ken there appears to be a healthy AS crayfish population in the northern part of the water body, down to Green Isle. There is then an area of low presence of AS crayfish down to Boreland of Parton. No records of AS crayfish have been reported in the lower section of Loch Ken or in the River Dee downstream of Loch Ken. Within Loch Ken there is a varied and diverse fish population, although many of the species are believed to have been introduced by anglers. Due to the spatial distance between the benthic living AS crayfish and the water column residing coarse fish species the only direct interaction between the species is likely to be in tributaries and the possible predation on fish eggs which will be attached to vegetation. It would also be expected that a number of the larger predatory fish species would be feeding on AS crayfish. This predation and possibly the substrate type and depth variation within Loch Ken may be presently slowing the downstream movement of the AS crayfish population. Discussions with SNH (personal communication, Knott) have suggested no particular sensitive biodiversity areas in the presently unpopulated section of Loch Ken which would be considered at risk from AS crayfish.

It is suggested that any attempted control of AS crayfish within Loch Ken would be problematic. The only practical method would be the use of modified traps. The GFT would suggest a number of possible concerns with any trapping strategy. Very little information is known of the size and distribution of the AS crayfish population within the loch. In fact there appears to be very limited research and information on large water body residing AS crayfish in the UK. The substrate area, and thus available AS crayfish habitat, within Loch Ken is substantial and if well populated may be entirely impractical to trap. SNH have also raised concerns relating to disturbance to nesting waterfowl if trapping was undertaken at sensitive times and locations. Possible vandalism of traps and practicalities of regular inspections of traps over a large expanse of water also need to be considered. On the other hand the questionnaire highlighted that many anglers have strong views that AS crayfish should be controlled within Loch Ken, in particular on the west bank. There is also an argument for trapping in the immediate vicinity of where the public is likely to come across AS crayfish, eg picnic sites, to limit the likely collection and further spread of the population.

It is suggested that prior to undertaking a possible trapping programme in Loch Ken that further research work should be undertaken to assess the exact distribution and abundance of AS crayfish within the loch. This work should also look at trapping efficiency within large still waters.

The River Dee, downstream of Loch Ken, is believed not to contain AS crayfish at present. The lower river is considered important for biodiversity reasons and contains the main Atlantic salmon spawning and nursery habitat of the catchment, as highlighted in electrofishing surveys (West Galloway Fisheries Trust 1996). Attempts should be made to ensure that the AS crayfish population does not leave Loch Ken. It is suggested that regular small-scale trapping is undertaken at the south end of Loch Ken near Crossmichael (NX728664) to provide an early warning when/if the present population expands to this point. This would allow a heavy trapping programme to commence in this area, similar to that undertaken on the upper Clyde, when required to attempt to control the spread of AS crayfish into the lower River Dee.

The literature review (see **Section 3**) suggested that predatory fish, in particular European eel, might be very effective in controlling AS crayfish populations (Svardson 1972; Furst 1977). As previously discussed, an electro fishing survey of 65 sites across the Kirkcudbrightshire Dee catchment in 1996 undertaken by the (West) Galloway Fisheries Trust failed to find any eels (West Galloway Fisheries Trust 1996). It would appear that eels have problems gaining access through the Tongland Salmon Ladder, which is situated at the river mouth. There are various designs for eel ladders/passes to assist with upstream migration of elvers over man made dams, which are used successfully in Sweden, Ireland and America. It is suggested that the possible construction of an eel ladder/pass at Tongland be explored. Wider biodiversity benefits would also result if a healthy eel population could be established in the River Dee and Loch Ken. It is not recommended to simply stock eels to AS crayfish infested areas as this would not be a long term solution, literature suggests that eels may not remain where introduced and similar experimental stocking work on the Clyde never recorded them again after release (personal communication, Miller).

7.1.2 Skyre Burn catchment

A previously unrecorded population of AS crayfish has been detailed in this report (see **Section 6**). It was agreed by SNH that this report, although initially commissioned to cover only the Kirkcudbrightshire Dee catchment, should be expanded to cover the new Skyre Burn population.

The Skyre Burn population still appears to cover a relatively limited geographical area with the main focus being the Laganmullen Burn. This small catchment contains a number of little ponds where the main population apparently resides. The lower section of the Skyre Burn appears, from trapping work undertaken by GFT, to support a low AS crayfish population. It would appear that the presence of bedrock, shallow depths and a high gradient may be limiting the suitability of the habitat. Limited trapping and a visual search by the GFT in the Skyre Burn, upstream of the Laganmullen Burn outflow, did not record the presence of any AS crayfish. Upstream movement may be hindered by obstructions. Atlantic salmon are unable to gain access to much of the catchment for the same reasons.

As this population appears to be only present over a limited area and the surrounding land owners appreciate the environmental harm that AS crayfish cause, it is suggested that a heavy control programme is considered with the ultimate aim of eradication.

This programme would focus on the Laganmullen Burn catchment as this small catchment supports a healthy AS crayfish population, and would appear to be supplying the recruitment for the lower Skyre Burn. Heavy trapping with modified traps would be undertaken in the pond systems. These sites are secure and unlikely to suffer from vandalism. The watercourse which connects the ponds, was also found to contain AS crayfish during visual surveys by GFT staff and this was confirmed during discussions with local residents. Very few

suitable areas exist for trapping in this small burn. It would though be a suitable watercourse for AS crayfish removal by electrofishing due to its limited width and depths, water clarity, accessibility, conductivity and has the support of surrounding landowners. Electrofishing would be undertaken regularly throughout suitable times of year. The visual survey suggested that the burn contains a number of very young AS crayfish including 0+, and electrofishing would be expected to be a suitable method to removal these early life stages. It is suggested that electrofishing should be undertaken during June–October when water temperature and AS crayfish activity should make technique more effective.

The lower Skyre Burn, downstream of the Lagganmullen Burn outflow, should be heavily trapped using modified traps. It appears that the AS crayfish population in this area is at a low density and is possibly relying on the Lagganmullen Burn for much of its recruitment. It is hoped that by controlling the Lagganmullen Burn population that this recruitment can be limited and trapping would then impact upon the resident population.

It is felt important that the possible future use of biocides should be considered for the Lagganmullen Burn catchment. These would be examined after trapping and electrofishing had taken place as a possible final method to achieve eradication, depending on the success of the other techniques. It could be used both in the ponds and Lagganmullan Burn. The literature review (see Section 3) suggested the most appropriate method would be the use of sodium hydroxide to raise pH and then deoxygenating using sodium sulphide or sucrose addition. The pH would then be neutralised and the water reoxygenated prior to its entry to surrounding sensitive waters. This would obviously cause extensive damage to the immediate aquatic ecosystem, although fish could be easily removed and returned later when conditions were suitable.

This drastic measure should only be considered as a final option if other options are unsuccessful and would require detailed discussions and agreement between a number of parties including the land owners, SEERAD, SNH and SEPA.

The ponds in many cases could be cut off from the watercourse and treated in isolation.

7.1.3 New future populations which may be discovered

It is crucial that if new populations of AS crayfish are discovered, or suggested to be present, that this information is responded to quickly. The possible success of eradication or control programmes are greatly enhanced if actions start as soon as possible after the introduction.

It is important to have a supply of readily available traps, suitable electrofishing equipment and personnel experienced with working on AS crayfish to respond to possible information quickly. It is suggested that if reports are substantiated then an assessment of the AS crayfish abundance and distribution should be undertaken and possible strategies for containment or eradication started swiftly.

7.1.4 General education programme

An education programme is required to highlight the concerns relating to AS crayfish and to publicise the present legislation. There was a strong indication from the questionnaire that people wish to be provided with more information.

The main aim at present must be to stop the further spread of AS crayfish into new catchments. All local AS crayfish populations appear to have been introduced intentionally. As the presence of AS crayfish in the Dee catchment appears to be well known by the local community it is important to highlight the ecological harm that the species can cause including to those involved in fisheries or conservation management.

Relevant legislation does not appear to be widely known or understood. It has been suggested that certain local residents involved in the sale of AS crayfish may have introduced AS crayfish to new waters for future harvesting purposes. A number of individuals appear to be presently trapping AS crayfish, presumably for consumption. At least two local hotels and two fish vans have been mentioned as regularly selling AS crayfish, which are described as 'local'. A mail order trap selling company based near Kirkcudbright have recently started selling crayfish traps.

It is suggested that a carefully thought out education programme should be implemented across Dumfries and Galloway region. It should be directed to educate two distinct groups, the local population and visitors. The main focus of the campaign should be highlighting the problems that AS crayfish cause and relevant legislation.

Press releases for local newspapers, radio and television stations would give regional coverage. On the Dee catchment specific publicity should be targeted to local schools, catering establishments and land/fishery owners, it is suggested that all owners who have land around the known AS crayfish populations should be approached to dissuade others from trapping. Anglers are an important group due to their potential to introduce AS crayfish through the misguided view of their suitability as fish food. Many are also unsure about what to do with captured AS crayfish. It is suggested that distributing information for the angling community could be co-ordinated by the GFT who have links to most fishery organisations within the region, including District Salmon Fishery Boards and angling clubs. Visiting anglers at Loch Ken could be supplied with information when purchasing a permit or from water bailiffs who inspect permits. Limited information is already provided in the Loch Ken boat registration leaflet.

Visitors to the Loch Ken area provide a quandary. There is a concern regarding highlighting to this group of the presence of AS crayfish as this may actually encourage their removal. It is though felt that it is important that there is a wider appreciation of the problems caused by AS crayfish and an awareness of relevant legislation by all visitors to the area. A lot of effort will be required to educate visitors and will require publicity around the Dee catchment, eg Loch Ken picnic sites, or in tourist centres and accommodation providers.

A further concern is that in the opinion of the GFT the main priority should be to locate the suggested new AS populations which may have recently been established. A publicity campaign which would highlight the legislation regarding illegality of introducing AS crayfish would be expected to discourage the reporting of these possible recent introductions.

It is suggested that the local community and visiting anglers should be the main focus for an education programme regarding AS crayfish. It is imperative that any education programme considered is not only short term. It is suggested that an annual programme is implemented to ensure the issues are well known to all.

8 TRIAL OF SUGGESTED METHODOLOGY

8.1 Introduction

The purpose of this research was to produce a strategy for the containment or possible eradication of AS crayfish. The main methods suggested in Section 6 were field tested. Although the literature review (see Section 3) has suggested that the methods described should work it is important to test their suitability for the local environments where they are required.

As described in Section 6, it was felt appropriate to trial trapping using modified traps versus unmodified traps in both main stem and side tributary conditions on the River Dee catchment and to undertake electrofishing work on the Skyre Burn catchment.

It must be pointed out that there was no use of control sites. For the electrofishing work it had been planned to undertake further experimental survey work but this was unable to be completed for reasons explained in Section 8.3.3. As detailed in the literature review (see Section 3) there is a requirement for a method of accurately estimating AS crayfish densities of all age classes ie the total population. Until such a method is devised it is extremely difficult to assess the effectiveness of any program of AS crayfish removal and not possible to know the population present at any control site.

It is important to appreciate that these trials were completed between December 2002 and February 2003 when water temperatures were low and AS crayfish activity is minimal. This would not be the preferred time of year to undertake the field trials but was necessary due to the timing of the contract award and stated timetable.

8.2 Trapping Trials

Further to discussions with SNH, it was decided to conduct two separate trapping studies. Two watercourses were selected that had been highlighted as areas with significant AS crayfish populations in the previous report undertaken by the West Galloway Fisheries Trust in 1999 (F99AC601). The two trial areas selected were the lower Garple Burn and the Water of Ken immediately upstream of the Garple Burn outflow.

Two separate trial areas were chosen to allow trapping success to be examined in two very different watercourse habitats. Instream habitats in the Garple Burn are significantly different from those in the Water of Ken (see Section 8.2.1.2).

8.2.1 Methods

8.2.1.1 Technique

Trapping was undertaken using commercial 'Swedish Trappies', of both cylinder and Tetra design. The cylindrical traps, dimension 50cm x 20cm, had diamond mesh of 33mm x 23mm apertures and a conical funnel entrance hole of 5cm diameter. The pyramidal tetra traps, dimension 38cm x 29cm, had diamond mesh of 30mm x 15mm and a conical funnel entrance hole of 4cm. A number of the traps were modified 'in-house' using fine gauge wire mesh of 20mm x 15mm mesh. This further reduced the mesh diameter on

the walls of the traps. On the modified traps, the funnel entrances were also modified using wire mesh to narrow the entrances to 2.5cm diameter. By using this method, it allowed the assessment of whether larger AS crayfish were deterred from entering modified traps. Additionally, it would help determine whether smaller AS crayfish could be captured and retained in the modified traps.

Some traps were set in pairs of one un-modified trap alongside a modified trap. These were set on long lines to allow the beaching of the traps should a period of high flow occur. Lines were attached to trees or staked securely into the bankside. Efforts were made to ensure each trap was actively fishing, however many traps had to be replaced during the experimental period due to losses incurred in periods of high flows.

It was assumed that both cylinder and tetra traps were equally effective at catching crayfish.

Rainbow trout was used to bait the traps. The trout were cut up and put in bait boxes which were placed inside the traps. Traps were re-baited every time they were checked for the presence of AS crayfish.

AS crayfish captured were measured (carapace length in mm), sexed and their reproductive status noted (whether the females were 'berried'). They were then humanely destroyed.

The temperature of the water was recorded each time the traps were visited. All equipment was thoroughly disinfected before and after use.

8.2.1.2 Survey sites

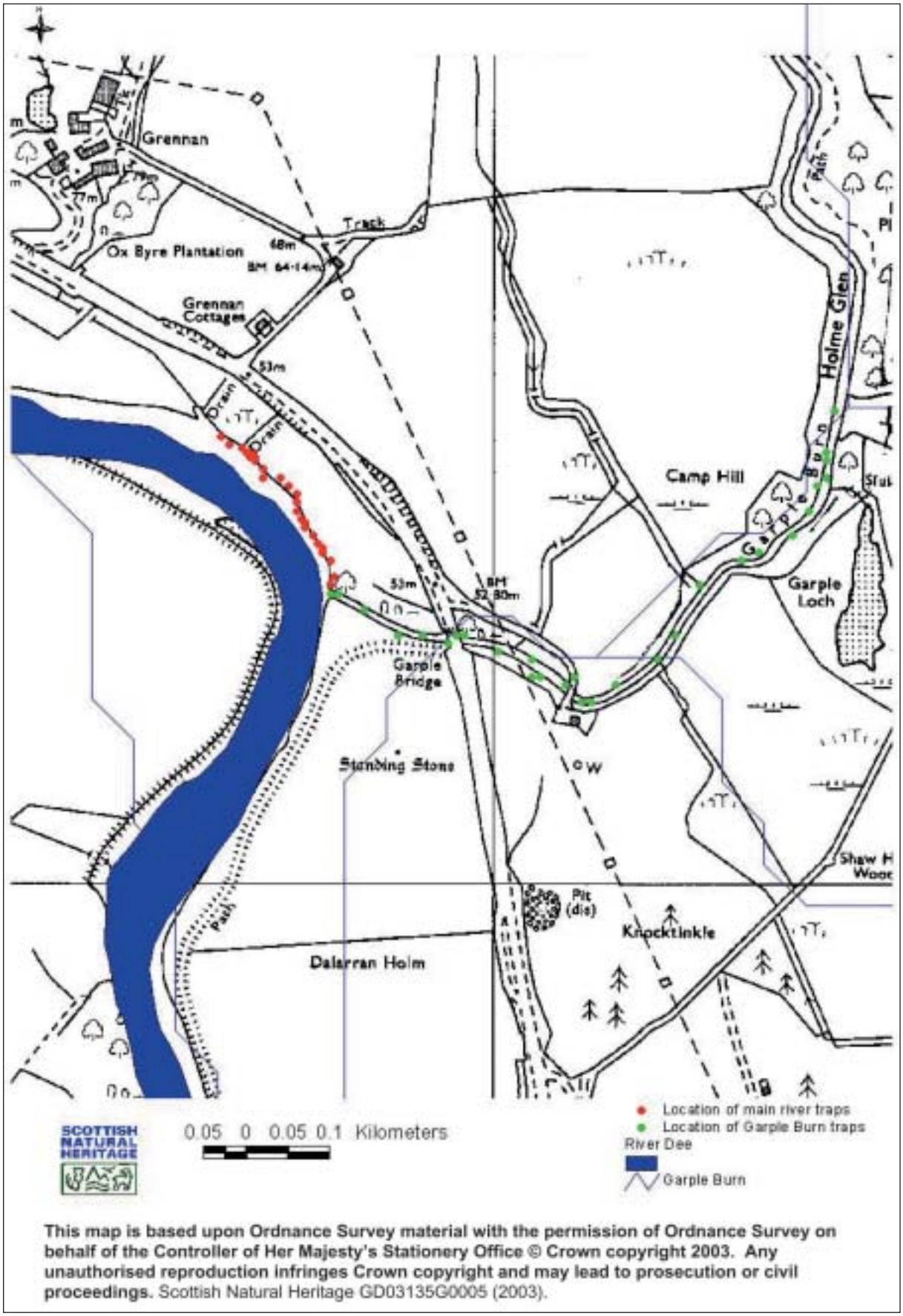
Trapping was undertaken between the 16th of December 2002 and 13th of January 2003 on the Garple Burn. Forty traps were set between grid references 263810: 579350 and 264410: 579570. Thirteen of these traps were modified, of which 12 were paired with unmodified traps. Trap locations are illustrated in Map 2.

Trapping was undertaken between the 13th of January 2003 and the 14th of February 2003 on the Water of Ken. Thirty-eight traps were set in the river between grid references 263810:570360 and 263660: 579600. Fourteen of these traps were modified, which were all paired with an unmodified trap. Trap locations are illustrated in Map 2.

The Garple Burn trapping sites were located within areas of rocky substrates dominated by cobbles, pebbles and boulders, although some finer sediment was evident at the lower end of the burn near the Water of Ken. Water depths were generally less than 30cm deep, however some traps were placed in an area of water that was 60–80cm deep. Flow types were a mix of shallow glide, run and riffle. The area was shaded by deciduous woodland, which also provided some limited bankside cover within tree roots. A small amount of draped bankside vegetation was present. Instream habitat was noted to be of a good quality.

The area of trapping on the Water of Ken demonstrated a contrast in habitat type to that on the Garple Burn. The main river presented a more 'classic' trapping environment as the river channel was deep and water depths were generally deeper than 1.5m. Water flows consisted of deep glide or run (depending on water height). Often flows were fast, resulting in the loss of some traps. Substrates consisted of sand, with some gravel and boulders. Much instream cover was available amongst roots of deciduous trees that lined the bankside. Instream habitat was recorded as being of a poor quality.

Map 2 Location of crayfish traps on the Garple Burn and the Water of Ken



8.2.2 Results

The results of the trapping trials are presented in Appendices 2 and 3, which provide trap number, trap type, modification status, paired status, water temperature, information on date surveyed, and the number/sex/length of AS crayfish captured.

8.2.2.1 Results – Garple Burn

Eight traps were lost during flood events, all of which were replaced.

Lower numbers of AS crayfish were captured than was expected from the Garple Burn. In total 51 AS crayfish were captured. Thirty-seven of these were males. Of the 14 females captured, eight were found to be 'berried'. These varied from lengths of 68mm to 110mm. The smallest AS crayfish was a male of 50mm and was captured in an unmodified tetra trap. The largest AS crayfish was a 'berried' female of 110mm which was caught in a modified tetra trap.

The traps caught AS crayfish continually until the 5th of January when no AS crayfish were recorded as being present in the traps. The greatest numbers of AS crayfish were recorded on the 1st of January when 19 males and 11 females, seven of which were 'berried', were captured. Water temperature on this day was 4 °C having been at 4 °C for the previous three trap visit days.

Of the AS crayfish caught 25 were in modified traps and 26 in unmodified traps. When examining all traps the average number of AS crayfish caught per trap was 1.92 for modified traps and 0.96 per unmodified trap. When only the paired traps were examined the average number of AS crayfish caught per trap was 2.0 for modified traps and 1.83 for unmodified traps.

The average carapace length of AS crayfish caught in modified traps was 76.52mm and in unmodified traps was 78.11mm.

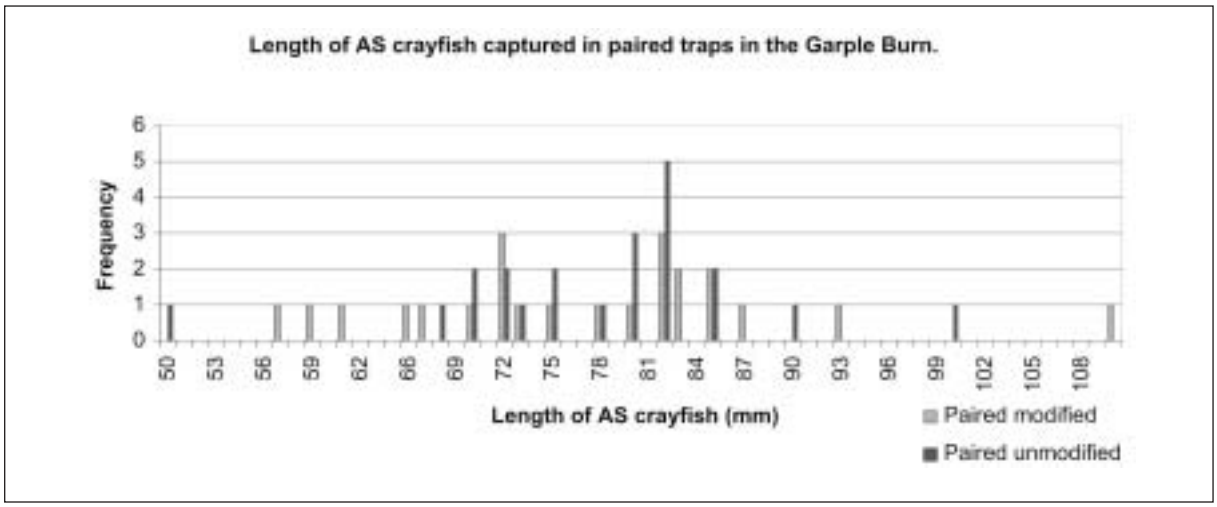
The difference in the number of AS crayfish captured between all the modified and unmodified traps in the Garple Burn was examined. A Mann-Whitney U-test was performed on the data and it was found that there was no statistically significant difference between the medians when comparing numbers of AS crayfish caught in modified and unmodified traps ($U = 91$; $P = >0.05$). Therefore, numbers of AS crayfish captured in both trap types did not differ significantly.

It was decided to test whether modified traps are statistically more effective at capturing AS crayfish in the Garple Burn, than unmodified traps when set in pairs. The Null Hypothesis predicted that there would be no difference in AS crayfish numbers caught between modified and unmodified traps. A Wilcoxon's Matched Pairs test was performed on the data and it was found that there was no statistically significant difference ($T = 16$; $N = 9$; $P = >0.05$). This means that the Null Hypothesis of no significant difference between the effectiveness between the modified and unmodified traps, must be accepted.

The difference in the number of AS crayfish captured between all the modified and unmodified traps in the Garple Burn was examined. A Mann-Whitney U-test was performed on the data and it was found that there is no statistically significant difference between the medians when comparing numbers of AS crayfish caught in modified and unmodified traps ($U = 91$; $P = >0.05$).

The difference in lengths of AS crayfish captured in paired modified and unmodified traps was analysed. A Kolmogorov-Smirnov test was performed on the data from the Garple Burn. The result showed that there was no statistically significant difference ($D\alpha$ = 0.405; D = 0.172). Therefore the Null Hypothesis of no significant difference in the lengths of AS crayfish captured between paired modified and unmodified traps must be accepted.

Table 3 Graph showing the lengths of AS crayfish captured in paired modified and unmodified traps on the Garple Burn



The lengths of AS crayfish that were captured in paired traps in the Garple Burn is shown in Table 3. Although the length distributions can be seen to vary between trap types, there was no statistically significant difference, as proved by the Kolmogorov-Smirnov test.

8.2.2.2 Results – Water of Ken

Eight traps were lost during flood events, all of which were replaced.

Higher numbers of AS crayfish were captured in the Water of Ken compared to numbers caught in the Garple Burn. In total, 155 AS crayfish were captured. 114 of these were males and 41 were females. Six of the females were 'berried'. The lengths of 'berried' female AS crayfish ranged from 71mm to 110mm. The smallest AS crayfish was a male which was 50mm in length and was captured in an unmodified cylinder trap. The largest AS crayfish captured was a male of 124mm in length which was caught in an unmodified cylinder trap.

The traps caught AS crayfish continually until 14th of February when the traps were removed. The greatest numbers of AS crayfish were recorded on the 24th of January when 26 males and 10 females, three of which were 'berried', were captured. The water temperature on this day was 7.3 °C and had been rising since the traps were put in on the 15th of January.

Of the AS crayfish caught 72 were in modified traps and 83 in unmodified traps. When examining all traps the average number of AS crayfish caught per trap was 5.14 for modified traps and 3.46 per unmodified trap. When only the paired traps were examined the average number of AS crayfish caught per trap was 5.14 for modified traps and 2.07 for unmodified traps.

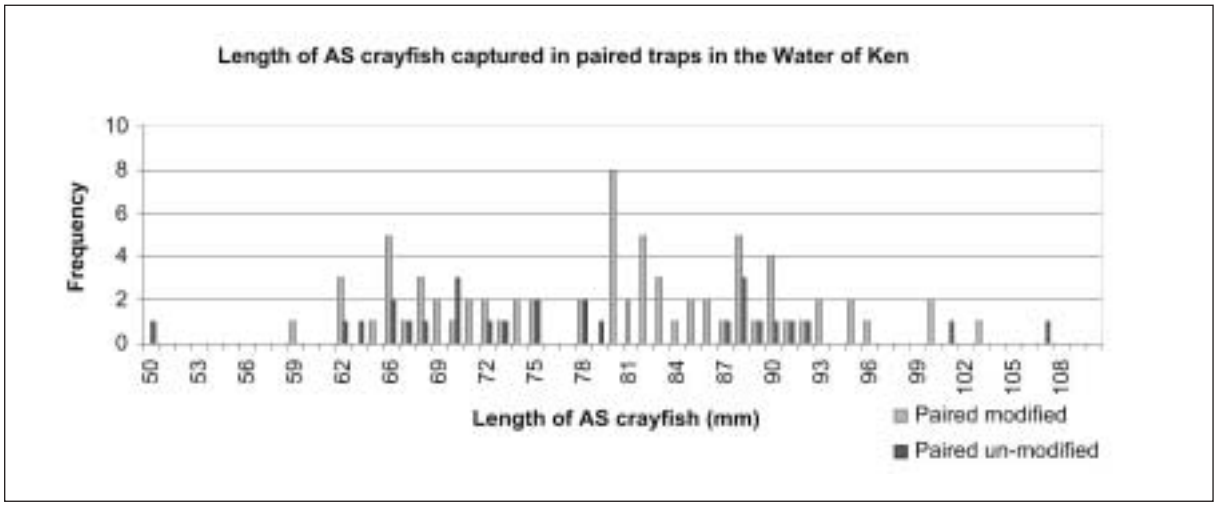
The average carapace length of AS crayfish caught in modified traps was 77.72mm and in unmodified traps was 88.63mm.

The difference in the number of AS crayfish captured between all the modified and unmodified traps in the Water of Ken was examined. A Mann-Whitney U-test was performed on the data and it was found that there was no statistically significant difference between the medians when comparing numbers of AS crayfish caught in modified and unmodified traps (U = 143.5; *P* = >0.05). Therefore, numbers of AS crayfish captured in both trap types did not differ significantly.

A test was carried out to ascertain whether modified traps were statistically more effective at capturing AS crayfish in the Water of Ken, than unmodified traps when set in pairs. The Null Hypothesis predicted that there would be no difference in AS crayfish numbers caught between modified and unmodified traps. A Wilcoxon's Matched Pairs test was performed on the data and it was found that there was no statistically significant difference (T = 13; *N* = 12; P = >0.05). This means that the Null Hypothesis of no significant difference between the effectiveness between the modified and unmodified traps, must be accepted.

The difference in lengths of AS crayfish captured in paired modified and unmodified traps was analysed. A Kolmogorov-Smirnov test was performed on the data from the Water of Ken. The result showed that there was no statistically significant difference (Dα = 0.306; D = 0.241). The Null Hypothesis of no significant difference between paired modified and unmodified traps must therefore be accepted.

Table 4 Graph showing the lengths of AS crayfish captured in paired modified and unmodified traps on the Water of Ken



The lengths of AS crayfish that were captured in paired traps in the Water of Ken is shown in Table 4. Although the length distributions can be seen to vary between trap types, there was no statistically significant difference between carapace length, as shown by the Kolmogorov-Smirnov test.

8.2.3 Discussion

In general, trapping was seen as a good method of capturing the larger age classes of AS crayfish within a specified area. However, it was felt that trapping conditions were not ideal and the number of AS crayfish estimated in the system was not reflected in trapping captures. Results from trapping work on the Clyde

showed that low catches were made during January–February 2002 probably due to low water temperatures. It can be assumed that similar problems existed during this study. Therefore, a representative sample of the total population was not gathered due to the time of year that the work had to be undertaken.

At both sites the modified traps were found to capture greater mean numbers of AS crayfish when compared to unmodified traps but following a more detailed examination of the numbers there was no statistical significance found. Similarly, the greater mean length of AS crayfish captured in modified traps was also not statistically significant.

It is felt that the limited captures made during these trials, due to the timing of works, may have limited the statistical significance of the findings. If future trapping is undertaken then further trials with modified traps would be recommended.

8.2.3.1 Garple Burn

The GFT feel that the Garple Burn is not the ideal location for conventional trapping methods. Water flows are generally low. However when a spate occurs the flow is very high energy and this, combined with rocky substrates, causes substantial damage to the traps. Trapping methods are best utilised where water is deep and flows are slow or back eddies are created. Larger AS crayfish appear to congregate in deeper, slower areas of water. Trapping in these areas would enable the greatest numbers of AS crayfish to be captured.

Additionally, the low water temperatures in the winter months, meant that the AS crayfish were much less active and did not travel far and therefore did not get captured within the traps.

Low captures in the Garple Burn may also be attributed to the burrowing habits of AS crayfish (see Clyde Visit, **Section 4**). However, few burrows were observed in the banks of the Garple Burn.

A limited 'hand' search was undertaken on the Garple Burn and no AS crayfish were observed. This was interesting as it had been suggested that in the summer months substantial numbers of AS crayfish can be observed under almost all of the cobbles near the burn's edge (personal communication, Ewing). A theory was developed by the GFT that, due to the time of year, the AS crayfish might be burrowing into soft banks or had moved downstream into the Ken to escape the worst of the low temperatures.

After statistical analysis of the data obtained from trapping on the Garple Burn, it was shown that there was no statistically significant difference between the numbers of AS crayfish captured in all the modified and unmodified traps. This was also true when the effectiveness of the paired modified and unmodified traps was examined. Furthermore, when the carapace lengths of AS crayfish captured in both modified and unmodified traps were compared, the results showed there was no statistically significant difference. As trapping conditions were not ideal ie the time of year trapping was undertaken, fewer AS crayfish were captured than expected, therefore sample sizes were considerably smaller than anticipated. If trapping had been undertaken for a longer period of time and at a more suitable time of year, the statistical analysis may have resulted in different conclusions.

It was suggested by trappers on the River Clyde (**Section 4.3**) that the trapping method of capturing AS crayfish is best suited to deep slow areas of water. Instream habitat conditions within the Garple Burn

presented difficulty when using conventional trapping methods and traps, as there were few deep areas in which to set traps.

8.2.3.2 Water of Ken

Greater numbers of AS crayfish were captured in the Water of Ken than in the Garple Burn. This may be because the concentration of AS crayfish is greater in the main river compared to the Garple Burn, or that the AS crayfish are relatively more active in the deep water of the Ken, ie – temperature fluctuations may not be as severe in the deeper water, therefore AS crayfish may remain relatively active. However, in the opinion of the GFT, the actual number of AS crayfish captured in the Water of Ken did not reflect the actual population density residing in this area. Once again low catches were also attributed to trapping during the winter months.

After statistical analysis of the data obtained from trapping on the Water of Ken, it was found that there was no statistically significant difference between numbers of AS crayfish caught in all the modified and unmodified traps. When the effectiveness of trapping AS crayfish in the paired modified and unmodified traps was examined, no statistically significant difference was observed. Similarly, when captured AS crayfish carapace length was compared between modified and unmodified traps, no statistically significant difference was found. Whilst trapping conditions were more suitable than those on the Garple Burn, fewer AS crayfish were captured than was expected. It may be the case that if sample sizes had been larger, the statistical analysis would have resulted in different conclusions.

8.2.4 Summary

The main points of the trapping experiment in the Garple Burn and the Water of Ken are summarised below.

8.2.4.1 Trapping trials undertaken on areas of the Garple Burn and the Water of Ken between 16/12/02 and 14/02/03, using 30–40 traps, some of which were modified.

8.2.4.2 Fifty-one AS crayfish were captured in the Garple Burn and 155 AS crayfish were captured in the Water of Ken.

8.2.4.3 Catches of AS crayfish were low compared to the numbers that were anticipated to be captured. It is thought that this is mainly due to the low water temperatures experienced at this time of year and the general inactivity of the AS crayfish.

8.2.4.4 AS crayfish at the larger end of the scale of those captured were caught in both unmodified and modified traps. The GFT suggest that to encourage smaller AS crayfish to enter and stay in the traps, further modification will be required.

8.2.4.5 Although the mean number of AS crayfish caught in modified traps was greater, this was not statistically significant.

8.2.4.6 Although the mean length of AS crayfish caught in modified traps versus unmodified traps was greater, this was not statistically significant.

8.3 Electrofishing Trial

A trial using electrofishing as a technique for removing AS crayfish was undertaken on the Lagganmullen Burn, a subcatchment of the Skyre Burn. This watercourse was highlighted in Section 6 as being suitable for electrofishing due to its limited width/depth, water clarity, accessibility and support from surrounding land owners for AS crayfish control to be undertaken.

8.3.1 Method

8.3.1.1 Data recording

The GFT is a partner in the Scottish Fisheries Co-ordination Centre (SFCC). All staff involved in the field work were accredited to relevant standards produced by the SFCC for electrofishing surveys and data collection. All electrofishing was completed to agreed SFCC formats.

It is the policy of the GFT to disinfect all relevant equipment both prior to and following work in each catchment to ensure that there is no transfer of disease organisms.

8.3.1.2 Technique

Electrofishing involves the creation of an electric field in the water to which AS crayfish respond by forced swimming or immobilisation.

The method of fishing used involved the anode operator working upstream drawing stunned individuals downstream to two hand net operators. The team works its way across the watercourse and upstream thoroughly fishing all the wetted area. Only one electrofishing run was made over the site on each date.

Collected AS crayfish were stored in buckets, anaesthetised using Benzocaine solution – Ethyl 4 – Aminobenzoate dissolved in Metholated Spirits. Once anaesthetised the AS crayfish were measured (carapace length in mm), sexed and their reproductive status noted (whether the females were berried). Then humanely destroyed. Any captured fish were released unharmed downstream.

The equipment used was a bankside generator electrofishing apparatus during all fishings. This equipment consists of a 1000 Watt Yamaha generator connected to a WFC 77-5 Electracatch control box. The control box is linked to a stationary cathode of braided copper and a mobile, single anode consisting of pole mounted, stainless steel ring and trigger switch.

This equipment can produce either smooth or pulsed direct currents while fishing. Pulsed direct current was used due to previous surveys suggesting this was the most effective for AS crayfish capture (Sinclair & Ribbens 1999).

The main survey site was electrofished on three separate occasions over a 40 day period.

The time taken to complete each survey was recorded to allow an assessment of effort to be made and to allow possible future survey works to be costed.

8.3.1.3 Survey site

The electrofishing site selected for AS crayfish removal was the lower 250m of the Laganmullen Burn. The site was marked with posts to ensure that each repeat survey covered the exact same area.

At the electrofishing site the burn flowed through two gardens and a deciduous woodland. Limited draped vegetation was present due to garden maintenance and excessive overhead shading from the mature forest. The substrate type varied with sections of fine silt where gradient was low, but the majority of the site was a mix of pebble and cobbles. Depths rarely exceeded 30cm and the wet width rarely exceeded 1m. Flow types were a mix of shallow glide and run with some limited riffle. A small amount of undercut habitat existed on both banks. In stream habitat was considered of poor quality.

8.3.2 Results

8.3.2.1 Figures presented

The results of the electrofishing survey are presented in Appendix 4, which provides information on date surveyed, start and finish time of survey, water temperature and the number/sex/length of AS crayfish captured.

The first survey was undertaken on 17/12/02 between 11.23am and 14.47pm. A three man electrofishing team fished for 204 minutes. A total of 54 AS crayfish were caught (31 males and 23 females). Of the females caught three were 'berried'. All female AS crayfish over 68mm were berried. It would appear that at least four distinct age classes were captured. A high percentage of the overall catch were considered 0+ (45% of males & 43.5% of females). The ratio of males to females captured was roughly 57:43.

The second survey was completed on 23/12/02 between 11.04am and 14.30pm. A three man team fished for 210 minutes. The exact same site length was surveyed as previously. A total of 17 AS crayfish were caught (10 males and 7 females). Of the females caught one was 'berried'. Once again a high percentage of the catch were considered 0+ (60% of males & 57% of females). The ratio of males to females captured was roughly 59:41.

The third survey was completed on 14/01/03 between 12.13pm and 15.32pm. A three man team fished for 199 minutes. A total of 15 AS crayfish were caught (9 male and 6 females). No 'berried' females were caught. Once again a high percentage of the catch were considered 0+ (67% of males & 67% of females). The ratio of males to females captured was roughly 60:40.

8.3.3 Discussion

As previously mentioned, it is important to appreciate that the electrofishing trial was undertaken during a time of year when the technique would not be considered as working efficiently or effectively. Water temperatures were low and at a level considered ineffective for use on fish. It is not known whether this situation is similar for AS crayfish. An additional concern is whether AS crayfish behaviour changes with low temperatures. Trapping success on the River Clyde (see Section 4.6) fell during December–June, with their

lowest month's catch during February. As mentioned in the literature review (see **Section 3.2.2.2**), during electrofishing AS crayfish become immobilised in their refuges within the substrate and in burrows and therefore may not be captured. Thus if AS crayfish behaviour, due to the time of year or water temperature, is encouraging the use of refuges then lower numbers would be expected to be caught. In addition AS crayfish may utilise the running water environment less during the winter and may prefer to reside in pond environments. This hypothesis is supported by the observations of local residents, who only see AS crayfish in the burn during the summer.

The main purpose of the electrofishing survey was to examine the practicality of the technique in the Laggamullen Burn.

The trial found that electrofishing could be undertaken successfully in the small watercourse. Water clarity, depths, accessibility, widths, substrate and water conductivity were all suitable.

From the limited survey work undertaken, electrofishing appeared to be successful for the capture of all age classes of crayfish. No other practical technique was suggested to be effective from the literature review for early age classes of AS crayfish apart from electrofishing and poisoning. The reduction in catch, even though similar effort and length of site was surveyed, would suggest that the technique was successfully depleting the population (ie 54, 17 and 15 respectively). There were no barriers to stop AS crayfish entering or leaving the site between surveys.

The average time to survey the 250m site was 204 minutes. This would suggest that approximately 500m of this burn could be surveyed by a three man team in a day. As there is a maximum of 900m of possible AS crayfish habitat in the burn it would take two full days to electrofish the available running water habitat in the burn.

It was not possible during this experiment to assess what proportion of the overall population was being removed. The GFT had planned further experimental work further upstream in the burn. Two 50m sections had been marked out where the wet width, riparian and instream habitats were similar. Each site was to be electrofished and the caught crayfish measured/sexed. At site one, all crayfish were to be killed once caught. At site two each crayfish caught was to be measured/sexed and then returned alive to the exact location it was captured from. By repeating this work at the same sites it would have been possible to have got an indication of the efficiency of the electrofishing removal technique compared to the control. This experiment had to be terminated when no AS crayfish were caught in the control site. The GFT had been reliably informed that during the summer AS crayfish are readily apparent at this location. As previously discussed, the time of year and water temperatures would be expected to be influencing behaviour and electrofishing efficiency.

It was disappointing not to have completed this further work as it would have indicated whether the efficiency of the equipment varied between the three survey dates.

8.3.4 Summary

8.3.4.1 An electrofishing survey was undertaken on the Lagganmullen Burn to examine the suitability of the technique for AS crayfish removal.

8.3.4.2 Electrofishing was undertaken on a 250m stretch of the burn on 17/12/02 (54 AS crayfish captured), 23/12/02 (17 AS crayfish captured) and 14/1/03 (15 AS crayfish captured). The same site and fishing effort were used for each survey. It took an average of 204 minutes to electrofish the 250m stretch of the burn.

8.3.4.3 Electrofishing was undertaken during conditions not believed to be optimal for AS crayfish capture, due to timing of contract offer and stated deadlines.

8.3.4.4 The electrofishing undertaken did appear to reduce the population of AS crayfish residing within the site.

8.3.4.5 The electrofishing undertaken appeared successful in catching all age classes of AS crayfish present, in particular the younger stages.

9 SUGGESTED STRATEGY FOR CONTAINMENT AND POSSIBLE ERADICATION OF AS CRAYFISH IN DUMFRIES AND GALLOWAY FOLLOWING TESTING OF METHODOLOGY

The suggested strategy for containment and possible eradication of AS crayfish has been formulated from the reasons given in Section 7 and Section 8.

As mentioned previously there is a requirement for a method of accurately estimating AS crayfish densities of all age classes to give the total population. Until such a method is devised it is extremely difficult to assess the effectiveness of any program of AS crayfish removal.

9.1 Kirkcudbrightshire Dee catchment

9.1.1 The natural upstream movement of the AS crayfish population has been stopped by Earlstoun Dam. Downstream of this dam the Water of Ken and associated tributaries contain AS crayfish down to Loch Ken. It is suggested that annual trapping with traps should be undertaken in the main Water of Ken. The use of modified traps should be explored further as while greater numbers of AS crayfish and greater average lengths were recorded in modified traps versus unmodified traps during the trials, there was no statistically significant difference between the trap types.

9.1.2 Trapping would be focused into key areas on the Water of Ken, where biodiversity benefits would be maximised eg salmon spawning/nursery habitat. There is though a limitation of where traps can be successfully set and expected to remain. This will require deeper water, in particular where the flow is reduced and close to the banksides. Increased instream cover from larger substrates and tree roots appears to support larger sized AS crayfish and higher densities, trapping in these areas will give greater catches.

9.1.3 Trapping trials found that trapping had limited success in tributaries due to water conditions (primarily a lack of depth) and possible seasonal changes in AS crayfish behaviour and distribution. Although a summer campaign of trapping would address the season problems it is envisaged that the distribution of the limited areas of suitable depths would result in trapping being too patchy to impact significantly on the AS crayfish population.

9.1.4 The suggested timings for a trapping programme would be during periods when conditions would be expected to result in maximum catches. This would appear to be between July and October, when water temperatures are increased and the problems of enhanced flows are reduced. Trapping in September would allow the increase in 'berried' females, as shown during the River Clyde work, to be collected.

9.1.5 Trapping strategy would be undertaken similarly to that used on the Clyde ie an area would be trapped until catches started to fall and then the traps would be moved downstream to a new area immediately downstream of the previously trapped area. This would then allow at the end of the trapping season an entire stretch to be identified where trapping had been completed.

9.1.6 It is suggested that up to 150 traps would be required to adequately trap the area between Earlstoun Dam and Loch Ken for four months annually.

9.1.7 Loch Ken supports an AS crayfish population which appears to be abundant between the north end of the loch and Green Isle. A few records were reported down to Boreland of Parton. The lower part of Loch Ken and the River Dee between Loch Ken and the estuary do not appear to presently support an AS crayfish population. It is suggested that regular trapping is undertaken in Loch Ken near Crossmichael to provide an 'early warning' when/if the AS crayfish population expands to this point. This would then allow a heavy trapping programme to commence to attempt to protect the Lower River Dee. It is suggested that the use of 30 traps used for 10 days every 3 months at suitable sites would be sufficient for the 'early warning' system.

9.1.8 Further research is required to assess the exact distribution and abundance of AS crayfish in Loch Ken. This work would also look at trapping efficiency within large water bodies.

9.1.9 Explore further the practicality of constructing an eel ladder/pass to encourage upstream migration of elvers over Tongland Dam.

9.2 Skyre Burn Catchment

9.2.1 In the Skyre Burn catchment the point of introduction and present main population of AS crayfish appears to be concentrated in the Lagganmullen Burn catchment. This small catchment has a number of man-made ponds which are linked to the burn. Discussions with locals has indicated that the burn and connecting ponds all contain a healthy AS crayfish population. It is believed that this catchment is providing the main AS crayfish recruitment for the lower Skyre Burn.

9.2.2 Electrofishing should be undertaken in the Laganmullen Burn to remove AS crayfish. This technique has been field tested and appears to be successful for removing all age classes. It is suggested that the length of the burn could be electrofished over two days (ie 500m a day) by a team of 3 trained personnel.

9.2.3 Electrofishing would be repeated 2-3 times between July and September, when water temperature and AS crayfish behaviour would be expected to result in greatest efficiency of AS crayfish removal.

9.2.4 In conjunction with the electrofishing work, the ponds on the Lagganmullen catchment should be heavily trapped using modified traps. Discussions with locals suggest a large AS crayfish population in these ponds. It is suggested that 10 traps should be set in each pond between July–October.

9.2.5 Trapping work should be undertaken on the lower Skyre Burn where a low density population of AS crayfish is present. It is believed that most of the recruitment for this area originates from the Lagganmullen Burn. Further work needs to be undertaken to investigate the exact distribution of AS crayfish in the lower section of the Skyre Burn.

9.2.6 Possible use of biocides should be considered for use on the Lagganmullen Burn in the future to achieve eradication, depending on the success of the trapping/electrofishing techniques.

9.3 Possible Future New Populations

9.3.1 The possible success of control or eradication programmes involving new populations is greatly enhanced if actions can be undertaken swiftly. It is suggested that a supply of traps is held within the region

to allow rapid assessment of abundance and distribution of any new population found. This would then allow a suitable programme of control to begin swiftly.

9.3.2 It is imperative to discover the possible locations of the recent introductions that have been suggested to the GFT.

9.4 General Education Programme

9.4.1 It is necessary to start an education programme highlighting concerns relating to AS crayfish and to publicise present legislation.

9.4.2 Specific targeted information should be concentrated towards local land owners, catering establishments/suppliers, anglers and children.

9.4.3 Press release for local newspapers, radio and television stations will be useful for informing the local population.

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APPENDIX 1 – Questionnaire on AS crayfish in the Ken/Dee system

Background

The Galloway Fisheries Trust (GFT) are conducting a project on American Signal Crayfish (*Pacifastacus leniusculus*) within the Kirkcudbrightshire Dee system. This species is not native to Great Britain and has spread rapidly across the Ken/Dee system in recent years. The project is focussing on the distribution and abundance of AS crayfish and possible containment strategies. This work is being undertaken for Scottish Natural Heritage. We would be very grateful if you could take a few minutes to complete the following questionnaire and return it to us in the enclosed pre-paid envelope by Monday 13th of January 2003.

Objective

The purpose of this questionnaire is to gauge the level of public awareness of AS crayfish within the Ken/Dee catchment, to collect further information on their distribution and abundance and to allow input from interested individuals and organisations.

All questionnaire responses will be treated in strict confidence and all information provided will be analysed in house by GFT. It will not be possible to identify individual respondents to the questionnaire. When reporting the findings only general discussion will be presented. The names of individuals or organisations who responded to the questionnaire will not be published.

Thank you for your time and co-operation. If further information is required please contact either Jamie Ribbens or Jackie Graham at the GFT offices on 01671 403011 or mail@gallowayfisheriestrust.org

1) Please indicate which group you feel best describes yourself

LAND OWNER / ANGLER / WATERSPORT USER / CONSERVATIONIST / CATERING / PROFESSIONAL BODY / OTHER (please specify)

_____

2a) Did you know that American Signal Crayfish are present within the Ken/Dee system?

YES/NO (delete as appropriate)

2b) If yes, roughly when and how did you find out?

_____

_____

_____

3a) Do you feel that the introduction of AS crayfish is of concern?

YES/NO (delete as appropriate)

3b) Why?

_____

_____

_____

3c) If yes to 3a, then please say what you feel should be done to address your concern.

_____

_____

_____

4a) Do you know where AS crayfish are present within the Ken/Dee system (including the streams)? If so, please specify locations

_____

_____

_____

4b) How did you find out where they were present? (delete as appropriate)

WORD OF MOUTH / SIGHTINGS / TRAPPING / WHILST ANGLING / MEDIA

5) Have you ever captured AS crayfish from the Ken/Dee system or its streams?

YES/NO (delete as appropriate)

If yes, by what method? (delete as appropriate)

ANGLING / TRAP / BY HAND

If so, please specify locations.

_____

_____

_____

6) Are there specific areas on the Ken/Dee system which you feel are particularly vulnerable to AS crayfish and if so, why?

_____

_____

_____

7) Do you know of any hotels/restaurants which presently have freshwater AS crayfish on the menu? If so, where?

_____

_____

_____

8) Do you know of any trapping/harvesting of AS crayfish in the Dee catchment taking place? If so where and for what purpose? **(NOTE Please do not identify individuals involved. We are only interested in where, how and why the activity is being carried out, not who is carrying out the activity).**

_____

_____

_____

9a) What do you think should be done with the AS crayfish present in the Ken/Dee system? (delete as appropriate)

NOTHING / HARVEST / CONTROL / ERADICATE / OTHER

9b) Please elaborate further.

_____

_____

_____

10a) Are you aware of any legislation regarding AS crayfish in Scotland?

YES/NO (delete as appropriate)

10b) If yes, please elaborate

_____

_____

_____

10c) Do you feel that the legislation should be strengthened or relaxed? Please mention any ideas you have.

_____

_____

_____

We would like to have the opportunity to discuss further some of the issues highlighted in the responses that we receive. If you are content to be contacted to discuss any issues further, please fill in your contact details below. **If you do not wish to be contacted please leave this section blank.**

_____

_____

_____

_____

_____

_____

APPENDIX 2 – Showing data from GFT AS crayfish trapping experiment on Garple Burn

Trap No.	Trap Type	Modified or Not?	Paired With	16/12/02 Water 4°C		20/12/02 Water 2°C		22/12/02 Water 2.5°C		24/12/02 Water 3.5°C	
				Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)
1	Tetra	No	2	0	0	0	0	0	0	N/A	N/A
2	Tetra	Yes	1	0	0	0	0	0	0	N/A	N/A
3	Cylinder	No	4	0	0	0	0	0	0	N/A	N/A
4	Cylinder	Yes	3	0	0	0	0	82	0	N/A	N/A
5	Cylinder	No	None	104	0	0	0	0	0	N/A	N/A
6	Cylinder	No	None	0	0	0	0	0	0	0	0
7	Cylinder	No	8	0	0	0	0	0	0	0	0
8	Cylinder	Yes	7	82	0	0	0	0	0	0	0
9	Cylinder	No	None	0	0	0	0	0	0	0	0
10	Cylinder	No	None	0	0	0	0	0	0	0	0
11	Cylinder	Yes	None	0	0	0	0	0	0	70	0
12	Tetra	No	None	0	0	0	0	0	0	0	0
13	Cylinder	No	14	0	82*	0	0	0	0	N/A	N/A
14	Cylinder	Yes	13	0	59	0	0	0	0	N/A	N/A
15	Tetra	No	16	0	0	0	0	50	0	N/A	N/A
16	Tetra	Yes	15	0	0	0	0	0	0	0	0
17	Cylinder	No	None	0	0	0	0	0	0	0	0
18	Cylinder	No	19	0	0	0	0	0	0	0	0
19	Cylinder	Yes	18	72	0	0	0	0	0	0	0
20	Tetra	No	None	M	M	0	0	0	0	0	0
21	Tetra	No	22	0	0	0	0	0	0	N/A	N/A
22	Tetra	Yes	21	0	0	0	0	61	0	N/A	N/A
23	Cylinder	No	None	0	0	0	0	0	0	0	0
24	Cylinder	No	None	0	0	0	0	0	0	0	0
25	Cylinder	No	26	0	0	0	0	0	0	N/A	N/A
26	Cylinder	Yes	25	0	0	0	0	0	0	N/A	N/A
27	Cylinder	No	None	0	0	0	0	0	0	0	0
28	Cylinder	No	None	0	0	0	0	0	0	0	0
29	Tetra	No	30	0	0	0	0	0	0	0	0
30	Tetra	Yes	29	93	0	0	0	0	0	0	0
31	Cylinder	No	32	0	0	0	0	0	0	0	0
32	Cylinder	Yes	31	0	0	0	0	0	0	M	M

APPENDIX 2 *(continued)*

Trap No.	Trap Type	Modified or Not?	Paired With	16/12/02 Water 4°C		20/12/02 Water 2°C		22/12/02 Water 2.5°C		24/12/02 Water 3.5°C	
				Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)
33	Cylinder	No	None	0	0	0	0	M	M	M	M
34	Cylinder	No	None	0	0	0	0	0	0	0	0
35	Tetra	No	None	0	0	0	0	0	0	0	0
36	Tetra	Yes	37	0	0	0	0	0	0	0	0
37	Tetra	No	36	0	0	0	0	0	0	0	0
38	Cylinder	No	None	0	0	0	0	0	0	0	0
39	Tetra	Yes	40	0	0	0	0	0	0	N/A	N/A
40	Tetra	No	39	0	0	80,85	0	80,85	0	N/A	N/A
Day Tot.	**-**	**-**	**-**	**4**	**2**	**2**	**0**	**5**	**0**	**1**	**0**

Key

* = Female 'berried'
M = Trap missing
N/F = Not fishing
N/A = Not accessible

APPENDIX 2 *(continued)*

Trap No.	Trap Type	Modified or Not?	Paired With	26/12/02 Water 4°C		28/12/02 Water 4°C		30/12/02 Water 4°C		01/01/03 Water 4°C	
				Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)
1	Tetra	No	2	0	0	0	0	N/A	N/A	0	70*
2	Tetra	Yes	1	0	0	0	0	N/A	N/A	0	0
3	Cylinder	No	4	0	0	0	0	N/A	N/A	N/A	N/A
4	Cylinder	Yes	3	0	0	0	0	N/A	N/A	N/A	N/A
5	Cylinder	No	None	0	0	0	0	N/A	N/A	0	0
6	Cylinder	No	None	0	0	0	0	N/A	N/A	0	0
7	Cylinder	No	8	0	0	0	0	0	0	0	0
8	Cylinder	Yes	7	0	0	0	0	0	0	0	0
9	Cylinder	No	None	0	0	M	M	M	M	M	M
10	Cylinder	No	None	0	0	0	0	0	0	0	0
11	Cylinder	Yes	None	0	0	0	0	0	0	0	0
12	Tetra	No	None	0	0	0	0	0	0	0	0
13	Cylinder	No	14	0	0	0	0	0	0	0	0
14	Cylinder	Yes	13	0	0	0	0	0	0	0	0
15	Tetra	No	16	0	0	0	0	0	0	0	0
16	Tetra	Yes	15	0	0	0	0	0	0	0	0
17	Cylinder	No	None	0	0	0	0	0	0	0	0
18	Cylinder	No	19	0	0	0	0	0	0	0	0
19	Cylinder	Yes	18	0	0	70	0	0	0	0	0
20	Tetra	No	None	0	0	0	0	0	0	0	0
21	Tetra	No	22	0	0	0	0	0	0	0	0
22	Tetra	Yes	21	0	0	0	0	0	0	0	0
23	Cylinder	No	None	0	0	0	0	0	0	0	0
24	Cylinder	No	None	0	0	0	0	0	0	0	0
25	Cylinder	No	26	M	M	M	M	M	M	M	M
26	Cylinder	Yes	25	M	M	M	M	M	M	M	M
27	Cylinder	No	None	0	0	0	0	73	0	0	0
28	Cylinder	No	None	0	0	0	0	0	0	0	0
29	Tetra	No	30	0	0	0	0	0	0	0	0
30	Tetra	Yes	29	0	0	0	0	85	0	0	0
31	Cylinder	No	32	0	0	0	0	0	0	0	0
32	Cylinder	Yes	31	M	M	M	M	M	M	70	0
33	Cylinder	No	None	M	M	M	M	M	M	M	M

APPENDIX 2 *(continued)*

Trap No.	Trap Type	Modified or Not?	Paired With	26/12/02 Water 4°C		28/12/02 Water 4°C		30/12/02 Water 4°C		01/01/03 Water 4°C	
				Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)
34	Cylinder	No	None	0	0	0	0	70	0	0	0
35	Tetra	No	None	0	0	0	0	0	0	0	0
36	Tetra	Yes	37	0	0	0	0	N/A	N/A	85	110*
37	Tetra	No	36	0	0	0	0	N/A	N/A	75	82
38	Cylinder	No	None	0	0	0	0	N/A	N/A	0	0
39	Tetra	Yes	40	0	0	0	0	N/A	N/A	75,65 83,87 82,67 73,72 57,83	78,72 80*
40	Tetra	No	39	82	0	0	73	N/A	N/A	78,82 70,82 72,90	100*,72 80*,75* 68*
Day Tot.	**-**	**-**	**-**	**1**	**0**	**1**	**1**	**3**	**0**	**19**	**11**

Key

* = Female 'berried'
M = Trap missing
N/F = Not fishing
N/A = Not accessible

APPENDIX 2 *(continued)*

Trap No.	Trap Type	Modified or Not?	Paired With	03/01/03 Water 3°C		05/01/03 Water 1.5°C	
				Male (mm)	Female (mm)	Male (mm)	Female (mm)
1	Tetra	No	2	0	0	0	0
2	Tetra	Yes	1	0	0	0	0
3	Cylinder	No	4	0	0	0	0
4	Cylinder	Yes	3	0	0	0	0
5	Cylinder	No	None	0	0	0	0
6	Cylinder	No	None	0	0	0	0
7	Cylinder	No	8	0	0	0	0
8	Cylinder	Yes	7	0	0	0	0
9	Cylinder	No	None	M	M	0	0
10	Cylinder	No	None	0	0	0	0
11	Cylinder	Yes	None	0	0	0	0
12	Tetra	No	None	71	0	0	0
13	Cylinder	No	14	0	0	0	0
14	Cylinder	Yes	13	0	0	0	0
15	Tetra	No	16	0	0	0	0
16	Tetra	Yes	15	0	0	0	0
17	Cylinder	No	None	0	0	0	0
18	Cylinder	No	19	0	0	0	0
19	Cylinder	Yes	18	0	0	0	0
20	Tetra	No	None	0	0	0	0
21	Tetra	No	22	0	0	0	0
22	Tetra	Yes	21	0	0	0	0
23	Cylinder	No	None	0	0	0	0
24	Cylinder	No	None	0	0	0	0
25	Cylinder	No	26	0	0	0	0
26	Cylinder	Yes	25	0	0	0	0
27	Cylinder	No	None	0	0	0	0
28	Cylinder	No	None	0	0	0	0
29	Tetra	No	30	0	0	0	0
30	Tetra	Yes	29	0	0	0	0
31	Cylinder	No	32	0	0	0	0
32	Cylinder	Yes	31	0	0	0	0
33	Cylinder	No	None	M	M	0	0

APPENDIX 2 *(continued)*

Trap No.	Trap Type	Modified or Not?	Paired With	03/01/03 Water 3°C		05/01/03 Water 1.5°C	
				Male (mm)	Female (mm)	Male (mm)	Female (mm)
34	Cylinder	No	None	0	0	0	0
35	Tetra	No	None	M	M	0	0
36	Tetra	Yes	37	0	0	0	0
37	Tetra	No	36	0	0	0	0
38	Cylinder	No	None	0	0	0	0
39	Tetra	Yes	40	0	0	0	0
40	Tetra	No	39	M	M	0	0
Day Tot.	**-**	**-**	**-**	**1**	**0**	**0**	**0**

Key

* = Female 'berried'
M = Trap missing
N/F = Not fishing
N/A = Not accessible

APPENDIX 3 – Showing data from GFT AS crayfish trapping experiment on Water of Ken

Trap No.	Trap Type	Modified or Not?	Paired With	15/01/03 Water 5.5°C		20/01/03 Water 6°C		22/01/03 Water 6.5°C		24/01/03 Water 7.3°C	
				Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)
1	Tetra	No	2	0	70	0	0	0	0	0	0
2	Tetra	Yes	1	0	0	N/A	N/A	0	0	0	0
3	Cylinder	No	4	0	0	N/A	N/A	0	0	0	0
4	Cylinder	Yes	3	0	0	0	0	0	0	0	0
5	Tetra	No	6	0	0	0	0	0	0	0	0
6	Tetra	Yes	5	0	0	N/A	N/A	87	0	0	0
7	Cylinder	No	8	N/A	N/A	N/A	N/A	0	0	0	0
8	Cylinder	Yes	7	N/A	N/A	N/A	N/A	M	M	84	0
9	Cylinder	No	None	0	0	N/A	N/A	0	0	0	0
10	Tetra	No	11	0	0	N/A	N/A	0	0	0	0
11	Tetra	Yes	10	0	0	N/A	N/A	0	0	90	0
12	Cylinder	No	None	92	0	N/A	N/A	M	M	0	0
13	Tetra	Yes	14	0	0	N/A	N/A	M	M	0	0
14	Tetra	No	13	0	0	N/A	N/A	0	0	101	67
15	Tetra	Yes	16	0	0	N/A	N/A	0	0	M	M
16	Tetra	No	15	0	0	N/A	N/A	78,89	0	92,88	0
17	Cylinder	Yes	18	N/A	N/A	N/A	N/A	0	0	0	0
18	Cylinder	No	17	88	0	N/A	N/A	M	M	M	M
19	Tetra	No	20	66	0	87,91	0	0	68	0	0
20	Tetra	Yes	19	0	0	N/A	N/A	0	0	88	0
21	Cylinder	No	None	0	0	N/A	N/A	0	0	0	0
22	Cylinder	No	None	0	0	N/A	N/A	0	0	0	0
23	Tetra	No	24	0	0	N/A	N/A	0	0	0	0
24	Tetra	Yes	23	0	0	N/A	N/A	0	70	0	0
25	Tetra	No	26	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
26	Tetra	Yes	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
27	Cylinder	No	28	0	0	N/A	N/A	50	0	0	0
28	Cylinder	Yes	27	0	0	N/A	N/A	0	0	0	75,69 71*
29	Cylinder	No	30	0	0	N/A	N/A	0	0	0	0

APPENDIX 3 *(continued)*

Trap No.	Trap Type	Modified or Not?	Paired With	15/01/03 Water 5.5°C		20/01/03 Water 6°C		22/01/03 Water 6.5°C		24/01/03 Water 7.3°C	
				Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)
30	Cylinder	Yes	29	80,82	0	N/A	N/A	82,82 80,65 86,93 100 72,80 90,95 86,82 83	75,78	85,80 89,92 80,95 103	0
31	Cylinder	No	None	102	0	N/A	N/A	81,95 85 104 98	0	0	85
32	Cylinder	No	None	N/A	0	N/A	N/A	0	0	0	0
33	Cylinder	No	None	N/A	0	N/A	N/A	100	80	100 78	0
34	Cylinder	No	None	N/A	0	N/A	N/A	0	0	0	0
35	Cylinder	No	None	0	0	0	0	0	0	86,83 103 95	110* 80* 104
36	Cylinder	No	None	124 118	0	107 84	0	0	0	90,86 106 90,78 93,91	100 104
37	Cylinder	No	38	0	0	M	M	0	0	0	0
38	Cylinder	Yes	37	0	0	M	M	0	0	0	0
Day Tot.	**-**	**-**	**-**	**8**	**1**	**4**	**0**	**24**	**5**	**26**	**10**

Key

* = Female 'berried'
M = Trap missing
N/F = Not fishing
N/A = Not accessible

APPENDIX 3 *(continued)*

Trap No.	Trap Type	Modified or Not?	Paired With	26/01/03 Water 7.8°C		28/01/03 Water 5.5°C		30/01/03 Water 5.5°C		02/02/03 Water 4.5°C	
				Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)
1	Tetra	No	2	0	0	0	0	0	0	0	0
2	Tetra	Yes	1	0	0	N/A	N/A	0	0	0	0
3	Cylinder	No	4	0	0	N/A	N/A	0	0	0	0
4	Cylinder	Yes	3	0	0	N/A	N/A	0	0	0	0
5	Tetra	No	6	0	0	90	N/A	0	0	0	0
6	Tetra	Yes	5	82	0	0	0	0	0	0	0
7	Cylinder	No	8	0	0	N/A	N/A	N/A	N/A	N/A	N/A
8	Cylinder	Yes	7	0	0	N/A	N/A	N/A	N/A	N/A	N/A
9	Cylinder	No	None	0	82	N/A	N/A	78	0	0	0
10	Tetra	No	11	0	0	N/A	N/A	0	0	0	0
11	Tetra	Yes	10	73,66	65	N/A	N/A	0	0	N/A	N/A
12	Cylinder	No	None	0	0	N/A	N/A	N/A	N/A	N/A	N/A
13	Tetra	Yes	14	80,78	88*	N/A	N/A	N/A	N/A	N/A	N/A
14	Tetra	No	13	0	0	75	0	0	0	73	0
15	Tetra	Yes	16	65	0	0	0	0	0	0	0
16	Tetra	No	15	0	0	N/A	N/A	0	0	0	0
17	Cylinder	Yes	18	M	M	M	M	N/A	N/A	N/A	N/A
18	Cylinder	No	17	0	0	N/A	N/A	N/A	N/A	N/A	N/A
19	Tetra	No	20	0	0	N/A	N/A	0	0	0	70,72
20	Tetra	Yes	19	59	0	0	68	0	0	66	0
21	Cylinder	No	None	0	0	N/A	N/A	N/A	N/A	0	0
22	Cylinder	No	None	0	0	N/A	N/A	0	0	0	0
23	Tetra	No	24	0	0	N/A	N/A	0	0	0	0
24	Tetra	Yes	23	64	0	N/A	N/A	0	0	0	0
25	Tetra	No	26	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
26	Tetra	Yes	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
27	Cylinder	No	28	0	0	N/A	N/A	0	0	N/A	N/A
28	Cylinder	Yes	27	0	0	N/A	N/A	N/A	N/A	N/A	N/A
29	Cylinder	No	30	0	0	N/A	N/A	N/A	N/A	N/A	N/A
30	Cylinder	Yes	29	0	0	N/A	N/A	N/A	N/A	N/A	N/A
31	Cylinder	No	None	0	0	N/A	N/A	N/A	N/A	N/A	N/A
32	Cylinder	No	None	86	0	N/A	N/A	N/A	N/A	N/A	N/A
33	Cylinder	No	None	0	0	N/A	N/A	N/A	N/A	N/A	N/A

APPENDIX 3 *(continued)*

Trap No.	Trap Type	Modified or Not?	Paired With	26/01/03 Water 7.8°C		28/01/03 Water 5.5°C		30/01/03 Water 5.5°C		02/02/03 Water 4.5°C	
				Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)
34	Cylinder	No	None	0	0	N/A	N/A	N/A	N/A	89	0
35	Cylinder	No	None	0	0	N/A	N/A	N/A	N/A	103	0
36	Cylinder	No	None	80	0	N/A	N/A	N/A	N/A	105	0
37	Cylinder	No	38	0	0	0	0	0	0	0	71, 98*
38	Cylinder	Yes	37	0	0	67,74	0	88	0	0	0
Day Tot.	**-**	**-**	**-**	**10**	**3**	**4**	**1**	**2**	**0**	**5**	**4**

Key

* = Female 'berried'
M = Trap missing
N/F = Not fishing
N/A = Not accessible

APPENDIX 3 *(continued)*

Trap No.	Trap Type	Modified or Not?	Paired With	05/02/03 Water 3.5°C		07/02/03 Water 3.5°C		09/02/03 Water 4°C	
				Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)
1	Tetra	No	2	0	62	0	0	0	0
2	Tetra	Yes	1	0	68	0	0	N/A	N/A
3	Cylinder	No	4	0	0	0	0	N/A	N/A
4	Cylinder	Yes	3	0	0	0	0	N/A	N/A
5	Tetra	No	6	0	0	0	0	N/A	N/A
6	Tetra	Yes	5	0	0	0	0	N/A	N/A
7	Cylinder	No	8	0	0	0	0	N/A	N/A
8	Cylinder	Yes	7	0	0	0	0	0	0
9	Cylinder	No	None	0	0	0	0	0	0
10	Tetra	No	11	0	0	0	0	N/A	N/A
11	Tetra	Yes	10	0	0	62,90	0	N/A	N/A
12	Cylinder	No	None	97,85	103	85 105	0	N/A	N/A
13	Tetra	Yes	14	0	0	0	0	N/A	N/A
14	Tetra	No	13	0	63	0	0	78	0
15	Tetra	Yes	16	0	0	0	0	0	0
16	Tetra	No	15	0	0	0	0	N/A	N/A
17	Cylinder	Yes	18	N/A	N/A	N/A	N/A	N/A	N/A
18	Cylinder	No	17	N/A	N/A	0	0	N/A	N/A
19	Tetra	No	20	0	0	0	0	79	0
20	Tetra	Yes	19	0	0	0	0	N/A	N/A
21	Cylinder	No	None	N/A	N/A	N/A	N/A	N/A	N/A
22	Cylinder	No	None	0	0	0	0	N/A	N/A
23	Tetra	No	24	0	0	0	0	N/A	N/A
24	Tetra	Yes	23	0	0	0	0	N/A	N/A
25	Tetra	No	26	0	0	0	0	N/A	N/A
26	Tetra	Yes	25	0	0	0	0	N/A	N/A
27	Cylinder	No	28	0	0	0	0	N/A	N/A
28	Cylinder	Yes	27	0	0	0	0	N/A	N/A
29	Cylinder	No	30	0	0	0	0	N/A	N/A
30	Cylinder	Yes	29	93,96 91,80 71,85 100	72,74 80,90*	83,88	0	N/A	N/A

APPENDIX 3 *(continued)*

Trap No.	Trap Type	Modified or Not?	Paired With	05/02/03 Water 3.5°C		07/02/03 Water 3.5°C		09/02/03 Water 4°C	
				Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)
31	Cylinder	No	None	105	0	90,86 103	0	N/A	N/A
32	Cylinder	No	None	N/A	N/A	0	0	N/A	N/A
33	Cylinder	No	None	N/A	N/A	0	0	N/A	N/A
34	Cylinder	No	None	N/A	N/A	96	0	0	0
35	Cylinder	No	None	99,93	0	0	0	N/A	N/A
36	Cylinder	No	None	91 108	0	0	0	N/A	N/A
37	Cylinder	No	38	0	0	0	0	0	0
38	Cylinder	Yes	37	0	0	0	0	0	0
Day Tot.	**-**	**-**	**-**	**14**	**8**	**10**	**0**	**2**	**0**

Key

* = Female 'berried'
M = Trap missing
N/F = Not fishing
N/A = Not accessible

APPENDIX 3 *(continued)*

Trap No.	Trap Type	Modified or Not?	Paired With	11/02/03 Water 5.2°C		14/02/03 Water 4.1°C	
				Male (mm)	Female (mm)	Male (mm)	Female (mm)
1	Tetra	No	2	0	0	0	0
2	Tetra	Yes	1	N/A	N/A	0	0
3	Cylinder	No	4	0	0	0	0
4	Cylinder	Yes	3	0	0	0	0
5	Tetra	No	6	0	0	0	0
6	Tetra	Yes	5	81	0	0	0
7	Cylinder	No	8	N/A	N/A	0	0
8	Cylinder	Yes	7	N/A	N/A	0	0
9	Cylinder	No	None	0	0	0	0
10	Tetra	No	11	0	0	0	0
11	Tetra	Yes	10	0	62	0	0
12	Cylinder	No	None	N/A	N/A	0	0
13	Tetra	Yes	14	N/A	N/A	0	0
14	Tetra	No	13	0	0	75	0
15	Tetra	Yes	16	83	0	0	0
16	Tetra	No	15	0	65	0	0
17	Cylinder	Yes	18	0	0	0	0
18	Cylinder	No	17	N/A	N/A	0	0
19	Tetra	No	20	0	0	0	0
20	Tetra	Yes	19	0	0	0	0
21	Cylinder	No	None	0	0	0	0
22	Cylinder	No	None	N/A	N/A	0	0
23	Tetra	No	24	0	70	0	0
24	Tetra	Yes	23	0	69	0	0
25	Tetra	No	26	N/A	N/A	0	0
26	Tetra	Yes	25	N/A	N/A	0	0
27	Cylinder	No	28	0	0	0	0
28	Cylinder	Yes	27	0	0	0	0
29	Cylinder	No	30	0	88,107	0	0
30	Cylinder	Yes	29	0	0	0	0
31	Cylinder	No	None	0	0	0	0
32	Cylinder	No	None	0	0	0	0
33	Cylinder	No	None	0	0	0	0

APPENDIX 3 *(continued)*

Trap No.	Trap Type	Modified or Not?	Paired With	11/02/03 Water 5.2°C		14/02/03 Water 4.1°C	
				Male (mm)	Female (mm)	Male (mm)	Female (mm)
34	Cylinder	No	None	0	85	0	0
35	Cylinder	No	None	0	0	0	0
36	Cylinder	No	None	0	0	0	0
37	Cylinder	No	38	0	0	0	0
38	Cylinder	Yes	37	0	88	68,81	62
Day Tot.	**-**	**-**	**-**	**2**	**8**	**3**	**1**

Key

* = Female 'berried'
M = Trap missing
N/F = Not fishing
N/A = Not accessible

APPENDIX 4 – Showing data from electrofishing experiment on Laganmullen Burn

Date of Survey	Start Time	Finish Time	D/s Grid Ref.	U/s Grid Ref.	Water temperature (°C)	Male Length (mm)	Female Length (mm)
17/12/2002	11.23	14.47	256700:555250	256450:555300	4.2	60	22
						88	24
						50	42
						42	91*
						80	68*
						64	44
						22	55
						36	21
						31	23
						21	39
						21	21
						24	20
						24	36
						24	26
						21	38
						55	41
						35	59
						42	42
						31	43
						42	21
						65	22
						59	40
						54	69*
						52	
						49	
						61	
						30	
						25	
						21	
						41	
						65	
23/12/02	11.04	14.36	256700:555250	256450:555300	2.5	55	68*
						62	24

APPENDIX 4 *(continued)*

Date of Survey	Start Time	Finish Time	D/s Grid Ref.	U/s Grid Ref.	Water temperature (°C)	Male Length (mm)	Female Length (mm)
						30	38
						21	22
						25	21
						24	42
						35	21
						42	
						49	
						23	
14/01/03	12.13	15.32	256700:555250	256450:555300	4.7	42	35
						45	21
						23	44
						22	23
						30	23
						65	40
						23	
						35	
						21	

* = Female 'berried'