THE DISTRIBUTION OF THE AMERICAN SIGNAL CRAYFISH (*PACIFASTACUS LENIUSCULIS*) IN THE DON RIVER CATCHMENT, SOUTH YORKSHIRE, UK

Don Catchment Rivers Trust

GRADUATE CONSULTANT:

CHRISTOPHER ARTHUR

PUBLICATION DATE:

31/08/2012

WORD COUNT: 9843

The Lancaster Environment Centre

LANCASTER UNIVERSITY

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Executive Summary

- The Don Catchment Rivers Trust commissioned a study of the distribution of the American signal crayfish, a deliberately introduced invasive species, in the vicinity of Sheffield in South Yorkshire.

- The specific aim of the project was to identify the source of the species introduction and to test the hypothesis that the distribution could be attributed to an introduction at a single site, from which the signal crayfish dispersed to their current locations. The evidence gathered did not support this.

- Historical records regarding previous locations where signal crayfish have been found were collated and used to focus an intensive trapping regime to map their current extent.

- The study tested 123 sites within the Don catchment were surveyed for both signal and native white-clawed crayfish during June and July 2012. This included the Rivers Don, Rivelin, Loxley, Sheaf and Rother, Blacka Dike, the Limb Brook, the Moss and the Shire Brook.

- 26 of these sites were found to contain signal crayfish in 5 isolated populations; located in the Moss, Shire Brook, River Rother, Black Dike and the River Rivelin.

- 3 sites in the Limb Brook were found to contain native white-clawed crayfish. The species was not found at any other locations.

- Geoinformatic systems (GIS) were used to produce maps showing previously known locations, the 2012 survey results and the presence of key environmental factors such as weirs and other barriers.

- The data presented here indicate that the current extent of the invasive signal crayfish has changed little in the recent past, with populations showing slower rates of dispersal than might be expected based on studies conducted elsewhere in the UK.

- Weirs were observed to present barriers to the invasion of signal crayfish in some locations, such as Beighton weir and Woodhouse Mill regulator on the River Rother, which appear to be limiting the species from colonising beyond these extents.

- Environmental variables were found to show little correlation with presence of signal crayfish, though the presence of riparian vegetation seems to have the greatest positive influence.

- Overall, these data indicate that the Don catchment supports several isolated populations of signal crayfish that are the result of multiple deliberate introductions. Rates of dispersal were seen to be slower than could be anticipated based on studies in other catchments in the UK, but in most cases substantial reaches of un-infested waterways are available to accommodate their spread. Based on the survey findings, a bias towards woodland river habitats was observed, though whether this is a preference exhibited by crayfish cannot be substantiated due to the high level of anthropogenic action in determining the presence of signal crayfish.

1. INTRODUCTION

1.1. THE DON CATCHMENT RIVERS TRUST

The Don Catchment Rivers Trust (DCRT) is a charitable organisation in South Yorkshire concerned with the conservation and rehabilitation of 3 major watercourses, and numerous smaller tributaries within the Don catchment. These are the River Don, the River Dearne and the River Rother. The Don flows for approximately 160km from its source to the Humber Estuary and occupies a catchment of 1719km^2. Tributaries add a further 160km to the length of the Don, the Rivers Dearne and Rother contributing 47km and 43.3km respectively. The work of the DCRT focuses on the water quality and hydrology of the rivers, and the flora and fauna that they support. Since the formation of the trust in 2005 they have collaborated with a number of organisations such as the Environment Agency (EA), the Yorkshire Wildlife Trust (YWT) and Crayfish Action Sheffield (CAS) to undertake projects to address these issues.

1.2. INVASIVE SPECIES

A perpetual concern of the trust is the detection and management of invasive species within the catchment. Invasive species are of considerable economic [1] and ecological [2] significance globally due to the loss of native biodiversity that they cause and the resulting disruption to valuable ecosystem services. Whilst the movement of species between areas and their subsequent colonisation is undoubtedly a natural occurrence, human activity has just as certainly increased both their range and frequency [3] and at a rate that continues to increase [4]. Introductions may be accidental or intentional, though in the latter instance species often become invasive where the risk is not fully appreciated and adequate precautions are overlooked [5]. In most freshwater ecosystems across the globe, non-indigenous species (NIS) present the primary or secondary anthropogenic impact [6] and therefore the issue of invasives is one of growing international importance and attention [7]. Numerous studies have identified negative impacts from introductions of exotic species, such as loss of natural biodiversity [8] and damage to ecosystem functioning [9]. The River Don catchment is host to a number of NIS such as American mink (*Neovison vison*), Himalayan balsam (*Impatiens glandulifera*), Japanese knotweed (*Fallopia japonica*) and signal crayfish (*Pacifastacus leniusculus*), which have a range of adverse effects on the ecosystem. For example it is well documented that the American mink has eradicated native populations of water voles (*Arvicola terrestris*) [10][11]. The invasion of the American signal crayfish in to the River Don catchment is the subject of this study.

1.3. AMERICAN SIGNAL CRAYFISH

Image 1. American signal crayfish. The characteristic 'signal' markings can be observed on the claws. Image obtained from http://canalrivertrust.org.uk/media/huge/595.jpg (23/08/2012)

Crayfish are aggressive predatory omnivores with a wide tolerance for a range of environmental conditions [12]. Exotic crayfish species are among the most commonly introduced aquatic organisms [13]. In the UK the most widespread and problematic of these is the American signal crayfish [14]. The signal crayfish is a native of western North America [15] and was introduced into Europe in the 1960s for aquacultural purposes [16]. In 1976 it became an invasive species in the UK, being introduced to waterways primarily through the aquaria trade, use as fishing bait and for harvesting as wild food [17]. By 1988 the species had colonised 250 bodies of water [18] and by 2010, non-indigenous crayfish outnumbered native species by two to one across Europe [13]. Estimates of population density range from 0.9 to 20 individuals per m^2 in UK and US waters [19] [20]. Nearly all catchments in southern England now support populations of signal crayfish, and whilst northern England shows a comparatively patchy distribution, their range is continuing to expand [21]. The presence of signal crayfish has been shown to be responsible for a plethora of undesirable consequences in the UK (and Europe as a whole), most conspicuously the associated decline of the only native British crayfish species; the white-clawed crayfish (*Austropotamobius pallipes*) [14]. Populations of the white-clawed crayfish are being replaced steadily by signal crayfish through a combination of competition for food and habitat [22] and there is evidence to suggest that the colonisation of an area by signals will replace native species completely [23]. Signal crayfish are responsible for the spread of crayfish plague, *Aphanomycess astaci*, for which they are a vector [24], whilst European species exhibit high susceptibility with close to 100% mortality rate among infected individuals [17]. Consequently the native white-clawed crayfish is listed as an endangered species on the IUCN Red list under criterion A2ce and their distribution is believed to have declined by 50-80% in England [25]. The fact that since 2009 the status of *A. pallipes* was upgraded from

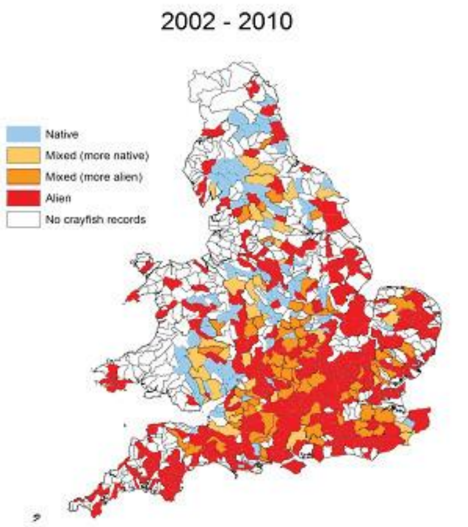

Figure 1 Distribution map of crayfish in UK sub-catchments (Nightingale & Holdich, 2011)

'vulnerable' to 'endangered' by the IUCN [26] shows the continuing severity of its plight. The waterways of central and northern England now exhibit the highest concentrations of white-clawed crayfish in Europe [27] and so conservation of their populations is of global significance. Signal crayfish are also seen to have an adverse effect on fish populations via competition and predation of eggs [28][29] and displacement of benthic species from shelter sites [30][31]. Similarly they are known to predate on amphibian and reptilian eggs and juveniles [32]. The ecological impact of these actions, combined with burrowing activities [17] and interactions with a wider range of aquatic organisms [28] is a severe loss of native biodiversity [33] which in turn has economic ramifications [34]). In recognition of the damage caused by signal crayfish, it is an offence to release them into the wild in the UK under section 9 of the Wildlife and Conservation Act 1981.

1.4. HABITAT

The wide environmental tolerances of signal crayfish allow them to occupy a greater range of habitats than the native white-clawed crayfish [35], in particular sites with lower water quality [36]. Whilst some studies do exist regarding the fine scale habitat requirements of crayfish, they are largely focused on single water bodies and so their robustness when applied over a coarse spatial scale cannot be determined [37][38][39]. There are several environmental factors that are frequently cited by studies of this nature as being of importance in identifying habitat as suitable for crayfish. Of these, the primary requirement is a high concentration of calcium (2.56mg L^{-1}) for calcification of their exoskeleton [35], this is often found in calcareous catchments where dissolution leads to high levels of dissolved ions in the channel. Another important factor influencing the suitability of a site for potential crayfish habitat is the presence of riparian vegetation to provide refuges [40] and shade [33]. Vegetation also provides sources of foods, via roots trapping leaf litter [41] and overhanging branches allowing invertebrates to fall into the water [42]. Crayfish are believed to show a preference for banks composed of clay soils as it provides a suitable substrate in which to create burrows [43], but poaching of soils by livestock has been seen to have an adverse effect on crayfish by both increasing sediment and agricultural loads in the water [37].

1.5. DISPERSAL

A number of studies have attempted to quantify the rates of invasion of signal crayfish in both upland and lowland river systems, though the range of estimates is vast. Dispersal of radio tagged crayfish in the upland River Wharfe in Yorkshire has been measured as 1.5km a year in 2004 [24] and 1.2km a year in 2008 [14]. Peay and Rogers [23] reported a rate of 1-2km a year in the same river, though a significantly lower upstream rate in a smaller tributary in 2009 [28]. In the latter case, the presence of a small waterfall was suggested as a factor in this reduced rate by barring progress. In a number of cases, expansion is seen to be greatest in a downstream direction [16][14], though the difference is not always seen to be significant. A study by Weinlander and Fureder in Austria [44] has recorded downstream colonisation of *P. leniusculus* at rates of up to 24km per year, and upstream at 4km. This is significantly higher than any UK based estimates, and higher temperatures in mainland Europe may be a factor in this instance. Crayfish size is observed to influence the preferred direction of movement, with smaller individuals moving downstream and only larger adults able to disperse upstream [14]. This is believed to be due to the physical strength required to actively move against the current. The effect of high flow events in passively transporting crayfish downstream has been reported by some studies [14] and may explain the variation in estimates provided by the studies cited previously. The substrate and presence of riparian vegetation of a river section is likely to influence this; sections with an abundance of refuges will allow crayfish to escape high flows whilst those unable to seek shelter will be washed downstream.

Gradient appears to have the largest influence on upstream colonisation, and so upland watercourses are invaded upstream substantially slower than less steep, lowland rivers [14][45]. A number of other factors are observed to influence these rates, such as water temperature increasing activity [16] and population density [19] suggesting that there are large seasonal and geographic variations between the invasion rates of separate populations. The relationship between size and movement of individuals is unclear with Moorhouse and McDonald [19] reporting a positive correlation, whilst Bubb et al [16][14] found no such link. Where expansion rates are unusually low, small obstacles such as weirs or waterfalls are offered as explanations [29][14]. The efficacy of barriers such as weirs to crayfish movement is an area that has received little attention but that would have obvious conservation benefits, both in selecting appropriate ark sites for native populations and in installing weirs etc. with suitable designs to prevent crayfish from traversing them. Dangerfield [46] states that many weirs in the vicinity of Sheffield are ineffective in halting crayfish due to gentle gradients, the presence of fish passes and films of algae to facilitate movement. Many weirs in the UK are being altered to include fish passes in order to comply with the Water Framework Directive (WFD) requirement of free passage to migratory fish [47]. Without careful consideration to their design and location, these fish passes have the potential to be navigated by signal crayfish past previously impenetrable barriers. It should also be noted that the ability of crayfish to leave the waterway and bypass barriers by terrestrial means needs to be taken into account. This information regarding dispersal is of significant value in predicting the spread of signal crayfish and in selecting sites to conserve for the benefit of native white-claws.

1.6. MONITORING

There are a number of possible techniques available for monitoring crayfish and these have been looked at in detail by Peay [48][49]. A summary of crayfish surveying methods and the required river conditions is shown in **Table. 1**. It is apparent that no single option is flawless, but that each possibility has advantages and disadvantages that will complement the environmental conditions likely to be encountered at a given site.

Table 1. Requirements, advantages and disadvantages of different survey methodologies for crayfish. The highlighted row shows the methodology utilised in this study

Method	Requirements	Advantages	Disadvantages
Manual Search (Standard method)	Clear Water <60cm depth	Able to search refuges Can catch juvenile individuals Can provide information on abundance, population structure etc.	Disturbs habitat Requires experience in identifying appropriate sites and in working safely near water Ineffective for bankside refuges
Manual Search (Fixed area)	Clear Water <60cm depth Slow flowing water	Can provide information on population densities	As above Labour intensive due to number of samples required
Trapping (Baited)	Moderate/slow flowing water	Can be used in deeper/more turbid waters when manual searches are impractical Relatively little effort	Only suitable for high population densities due to inefficiency Traps may be expensive Traps may be vandalised Care needed to prevent accidental trapping of non-target species Only catches **active** adults
Trapping (Un-baited)	Moderate/slow flowing water	Traps can be left for extended periods Catches juveniles as well as adults No risk to non-target species	Traps must be made Traps may be tampered with Availability of natural refuges will affect efficiency – varies between sites/conditions
Night Surveying	Clear water <1m depth Moderate/slow flowing water	Minimal disturbance as individuals are not caught No risk to non-target species	Safety considerations due to night working Requires calm water Prevents conclusive species ID without catches Affected by seasonal/behavioural/environmental responses

This study used baited trapping due to the range in size of the rivers to be surveyed. Whilst smaller tributaries such as the Moss or Shire Brook would be suitable for manual searches, the main body of the Rivers Don and Rother are far too deep and wide to accommodate such methods. Trapping is known to require relatively high abundances due to its low efficiency [48] and to show bias towards larger individuals [49]. A study by Silver [50] in the Huddersfield canal calculated trapping to have caught 2-4% of the number of potentially trappable individuals, though this will vary between populations depending on the age and size structures of the population, microhabitat use and the number and location of traps used [49]. Factors such as the type of bait used and water temperature [48] will also influence the actual numbers caught. Data obtained

Image 2. The River Don in Sheffield city centre. Image obtained from http://s0.geograph.org.uk/geophotos/02/37/42/2374201_00757589.jpg (23/08/2012)

from trapping is therefore of limited use in attempting to calculate actual population densities, or in comparing numbers between studies using even slightly different methods. Nevertheless, catch per unit effort provides a useful tool for comparing differences between sites surveyed as part of a study where variables are controlled as closely as possible, or in detecting change over time [51][52]. Trapping also has the potential of capturing non-target organisms. This can be reduced with the inclusion of an otter guard to restrict the entrance to the traps.

1.7. MANAGEMENT

Previous attempts to eradicate populations of signal crayfish have been largely ineffective [53]. The only method that appears to work is the use of chemical biocides, though the widespread and indiscriminate damage that they cause to an ecosystem makes them unacceptable in virtually all circumstances [54]. Removal by trapping can decrease numbers of the larger size classes that are able to be caught but leaves juvenile populations almost entirely untouched [19]. This is observed to have little effect on the overall population in the long term [55]. A study by Moorhouse and McDonald [19] suggests that this may be useful in slowing spread at the peripheries, but acquiesce that ultimately no trapping programme will be effective in stopping their spread. In the early 21st century, extensive trapping and manual removal of signal crayfish was conducted on the River Sheaf in Sheffield, but this too proved unsuccessful.

2. PROJECT OBJECTIVES

2.1.1. PRIMARY OBJECTIVE

The primary objective of this study was to examine the spread of signal crayfish through the rivers of the Don catchment to determine the extent and rate at which they have progressed, and to attempt to elucidate the origins of their introduction to the system. This allowed the hypothesis that the current populations are a single population (or meta-population) that emanated from a single point of introduction, rather than numerous discrete populations resulting from isolated introductions to be tested. This has been achieved by conducting a survey of their current distribution to reveal any links between the populations, the existence of which would support the hypothesis. It was believed that information regarding the introduction of the species to the area which would be of conservation value in protecting native white-clawed populations. This information will be of significance as it will reveal how the organisms are continuing to colonise new sites, often isolated from other populations. Once this is known, steps may be taken to prevent any future spread and to protect species, such as white-clawed crayfish, that may be harmed by the presence of signal crayfish.

2.2.SECONDARY OBJECTIVES

Several secondary objectives were undertaken in this study. The rate of dispersal of crayfish within the catchment was calculated by comparing their current distribution with that of a known time period from previous records. Several studies have been conducted in the UK regarding the rates of movement of signal crayfish [16][14][20][23][19], and these estimates will allow comparisons to be drawn against crayfish dispersal in other locations. The efficacy of various obstructions, such as weirs, culverts and roads, would be assessed as barriers to invasive crayfish movement by recording their presence and comparing locations to crayfish distribution. Environmental data such as land use will be collected to enable inferences to be drawn regarding habitat preferences for the species.

There is a possibility that there are still strongholds for the native white-clawed crayfish within the catchment, other than the known sites on the Porter and Limb Brooks. Whilst known sites such as the Porter Brook were avoided to minimise distrubance, it was hoped that any such populations would be uncovered in the course of the study so that appropriate actions can be taken for their preservation. It is also beneficial to record the location of current signal crayfish populations in relation to the aforementioned native populations to determine the threat that their continued expansion may pose.

3. METHODOLOGY

3.1. PREVIOUS LOCATIONS – SYNTHESIS OF MAPS USING ARCGIS

Initially, a GIS map was constructed to document the known populations of signal crayfish from previous surveys. These data was obtained from Crayfish Action Sheffield (CAS) and the DCRT and features results from surveys conducted by the EA, CAS, local councils and Sheffield Wildlife Trust (SWT), as well as casual reports from fishermen and members of the public. The data set spanned a large time period from 1980 to 2010, with the majority of the dates falling in the early part of the 21st century. Easting and Northing co-ordinates were present for each sample location and these were plotted as XY points on ArcMap10[1] over an Ordnance Survey 1:25000 basemap of the area obtained from the Edina Digimap service[2]. Superficial and underlying geology information was also secured from Digimap to provide an environmental perspective to the location of signal crayfish populations. All imagery and data were orthorectified to ensure their geometric uniformity and projected onto the British National Grid to ensure maximum compatibility between layers. Information regarding potential barriers to dispersal such as weirs, culverts, dams etc. was collated from CAS, the EA, Ordnance Survey (OS) and field observations and the locations were highlighted to identify areas of particular interest in assessing the rates and mechanisms of crayfish dispersal.

3.2. SITE SELECTION

Locations known to previously support signal crayfish (see above) provided the starting points for a new survey conducted from June to mid-August 2012. As the historical records were dated, estimates were made regarding the dispersal of signal crayfish, based on previous studies in other catchments. The historic data points were re-sampled to confirm the presence of signal crayfish and new sites were selected both upstream and downstream from these locations to determine the extreme spatial distribution of each population. Sites were identified at 0.5km intervals after consultation with Paul Bradley (a Yorkshire based ecological consultant with considerable expertise in conducted crayfish surveys) as this was considered an achievable spatial resolution given the length of the watercourses and the time frame available for fieldwork. These distances were not achievable in all cases due to the termination of the waterway prior to that point or a lack of safe access to the watercourse, particularly in the case of the River Rother south of its confluence with

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[1] www.esri.com (Accessed 3rd August 2012)

[2] http://edina.ac.uk/digimap (Accessed 3rd August 2012)

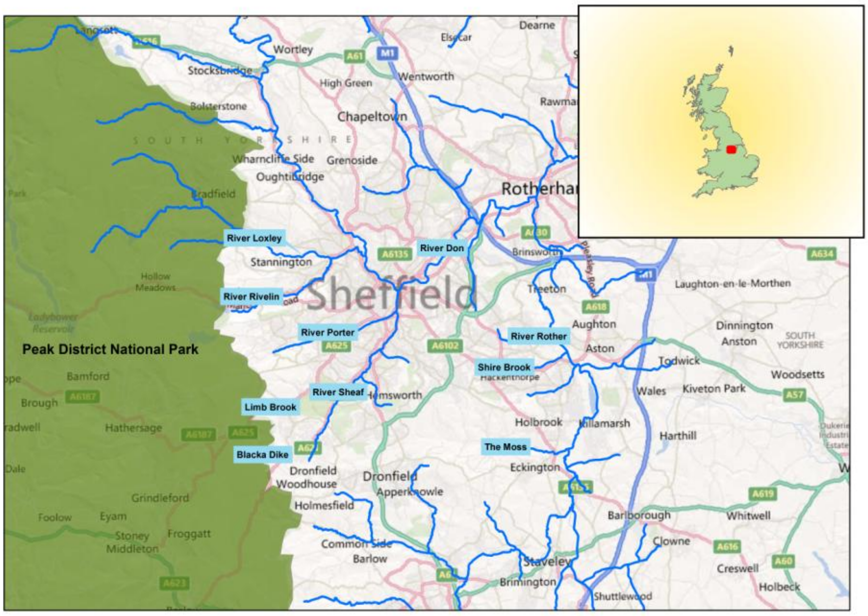

Figure 2. Map showing location of the River Don catchment, and the various waterways within it.

the Don. In such instances the stream or river was surveyed at a corresponding distance in the body of the stem river, or at the nearest suitable location. Due to the presence of signal crayfish at a single site on the River Rivelin, the stretch of river was sampled at a higher resolution of 100m in order to ascertain the true geographic extent of the population. Despite falling in the DCRT's responsibility, the River Dearne was excluded from this study due to the time restraints faced by the author and the rivers comparative isolation from the rest of the study area. It was decided that the River Dearne would not prove essential in testing the hypothesis of the investigation.

Trapping focussed on the body of the River Don and its largest tributaries; the River Sheaf and the River Rother. The intermediary river sections between sites where signal crayfish were present were considered of highest importance. Finding a connective link between populations would support the hypothesis that all signal crayfish in the catchment are the result of a single introduction, whereas substantial gaps between isolated 'clusters' would suggest that there have been numerous points of entry. Certain additional locations were selected as being of particular interest, either because of opinions expressed by the DCRT, or due to their proximity to environmental anomalies such as weirs. Conversing with members of the public during fieldwork uncovered several reports of signal crayfish sightings that had not previously been recorded. These reports are recorded in this document, and were sampled by the author in each instance.

The Porter Brook (a tributary of the River Sheaf) was designated as an ark site for native white-clawed crayfish by CAS, due to the healthy population that it sustains. For this reason no trapping was conducted on this watercourse to minimise the disturbance to known populations of the native crayfish. The Limb Brook, another tributary of the Sheaf slightly higher upstream than the Porter, has also been shown to support native white-clawed crayfish, but was sampled in this study due to records showing that signal crayfish were beginning to encroach on their position.

3.3. SURVEYING

Image 3. Example of the crayfish traps used in this study. Image obtained from http://ecx.images-amazon.com/images/I/51rw3CdDaRL._SL500_AA300_.jpg (23/08/2012)

Due to the river conditions found within the River Don catchment, trapping was selected as the most appropriate survey methodology, despite the fact that it is known to have relatively low efficiency [48]. Prior to commencing any fieldwork, authorisation was obtained from the Environment Agency to use instruments other than rod and line to remove fish, yielding the trapper number EW019-Z-889. The traps used were conventional, collapsible lobster pots that are frequently used in this nature of study (**Image 3.**). These pots provide a cheap and easily transportable method of surveying and are easily tailored to comply with legislation authored by the Environment Agency [56]. This specifies that traps must not exceed 60cm in length and 35cm in width and consist of mesh <3cm with an opening of <9.5cm. These regulations are primarily to protect other species such as otters being unintentionally trapped, and were rigidly adhered to throughout all field studies. As a further deterrent, cross wires were added to each trap entrance. Traps were baited using mackerel and replenished at each submersion. This was kept constant at all sites throughout the surveying to prevent any bias arising from variable trapping methodologies. A total of 16 traps were procured which were deployed in pairs at intervals of 0.5km along watercourses and left for 24 hours before being removed. This allowed 8 sites to be surveyed per day covering a distance of approximately 4km. Trapping only took place during periods of normal or reduced flows, where water speed did not exceed 25 metres per second; it is believed that higher rates than this would reduce the foraging activity of crayfish and force them into refuges, thus would be likely to produce erroneous results and potentially false positives. At each site the following data was recorded; species of crayfish present, number of individuals in each trap, depth of survey site and length of crayfish.

During the course of fieldwork, the author also questioned several fishermen and members of the public about locations where signal crayfish have been sighted within the catchment. Whilst unsubstantiated and unquantifiable, anecdotal evidence such as this is invaluable in identifying sites where crayfish have been found, particularly where they do so at densities low enough to miss detection by trapping.

The biocide Trigene was used to disinfect all equipment after each session to comply with standard biosecurity measures, ensuring that no organisms or diseases (particularly crayfish plague) were transferred between sites. In compliance with the Wildlife and Countryside act 1981, which states that it is an offence to release a non-native species into the wild, all captured signal crayfish were removed from the site having been killed humanely. Consideration was given to the exact location of traps within a site to minimise their visibility for two reasons; firstly to reduce the likelihood of interference by members of the public, and secondly to limit the interest that may be generated by wild food enthusiasts or other groups that may potentially be encouraged to engage in trapping activities without legal consent or appropriate biosecurity measures. To reinforce this latter point, the deployment and harvesting of traps was performed when the number of members of the public was likely to be minimal.

3.4. ANALYSIS/INTERPRETATION

The results of the 2012 survey were overlaid onto the GIS map to show changes in the distribution of signal populations against historical records. The rate of dispersal for each watercourse was calculated by comparing the current extent of the population with that of a known date obtained from existing records. Locations of barriers within waterways were contextualised against the movement of crayfish to assess their efficacy in limiting their spread. The use of OS maps as a base layer allowed elements of environmental interest, such as woodlands, to be extracted from the map. Data of catch per unit effort was calculated for each site by averaging the number of individuals between the two traps. This was then summarised to give a figure for the waterway as a whole.

3.5. TIMELINE

The initial stage of the project was the creation of a GIS database of signal crayfish distribution within the catchment. This information was provided by CAS and the DCRT in the first few weeks and was overlaid on OS map, geology and catchment data. Survey sites were identified from this information and trapping was performed in the summer months of June, July and August. Prior to this, the author obtained all necessary equipment such as traps, and ensured that he was acquainted with all regulations regarding licensing and biosecurity. Care was taken to ensure that all plans adhered to relevant health and safety regulations (eg. working near water, lone worker protocol). These were achieved by consultation/training (as needed) with CAS, DCRT, EA and/or Paul Bradley in the latter half of April and May. In these initial stages of the project, introductory and planning aspects of the report were written to alleviate pressure later on that would be imposed by the late and intensive trapping effort. Due to the optimum surveying period for signal crayfish running into August, the results and discussion components were completed towards the end of the project timeline. With good time management and appropriate preparatory work this did not prove to be a problem. A Gantt chart depicting the proposed timeline for various tasks created at the submission of the interim report is included in Appendix A.

4. FINDINGS

4.1. REPORTS FROM THE PUBLIC

4.1.1. MALIN BRIDGE - THE CONFLUENCE OF THE RIVERS LOXLEY AND RIVELIN (SK324894)

Signal crayfish were reported to have been found during a fishery survey at this location by Paul Gaskell of the Wild Trout Trust via email correspondence. No crayfish were found at this site during this study, though they were found slightly upstream, adjacent to the fishing pond at Walkley Bank.

4.1.2. SALMON PASTURES - THE RIVER DON (SK378893)

A local fisherman reported having caught signal crayfish in the vicinity of the Salmon Pastures nature reserve on the River Don. This stretch of river was sampled at 500m intervals with no trace of crayfish being found. The authenticity of this report can therefore not be confirmed.

4.1.3. CATCLIFFE FLASH - THE RIVER ROTHER (SK424880)

A local fisherman reported catching a single individual at this location on the River Rother, and provided photographic evidence to support their claim. Sampling at 500m intervals found no crayfish on this stretch of river, though upstream in the Woodhouse Washlands nature reserve, the Rother was found to support signal crayfish at a high density. The Woodhouse Mill regulator marks the end of the population found in this study, and is approximately 1.5km upstream of the reported sighting.

4.1.4. BIRLEY SPA POND - FEEDING INTO THE SHIRE BROOK (SK409837)

A member of the ShireBrook heritage group reported a person claiming to have introduced Signal crayfish into the pond at Birley Spa with the intention of cultivating them for profit. If this was accurate, it could explain the origins of the species into both the Shire Brook (into which the pond feeds via Carr Forge pond) and ultimately the River Rother. Surveying found no trace of the species in the pond, and the stream eminating from it was unsuitable for trapping due to being very shallow and at a steep gradient, though extensive numbers of signal crayfish were found in the Shire Brook itself.

Whilst the author was shown this site in person, there is a possibility that the pond being referred to as having signal crayfish deliberately introduced was actually one at Birleyhay on the River Moss. This is a short distance away and has previously been recorded as being heavily populated by signal crayfish. The introduction of the species here for aquaculture could also offer an explanation as to their introduction into the system.

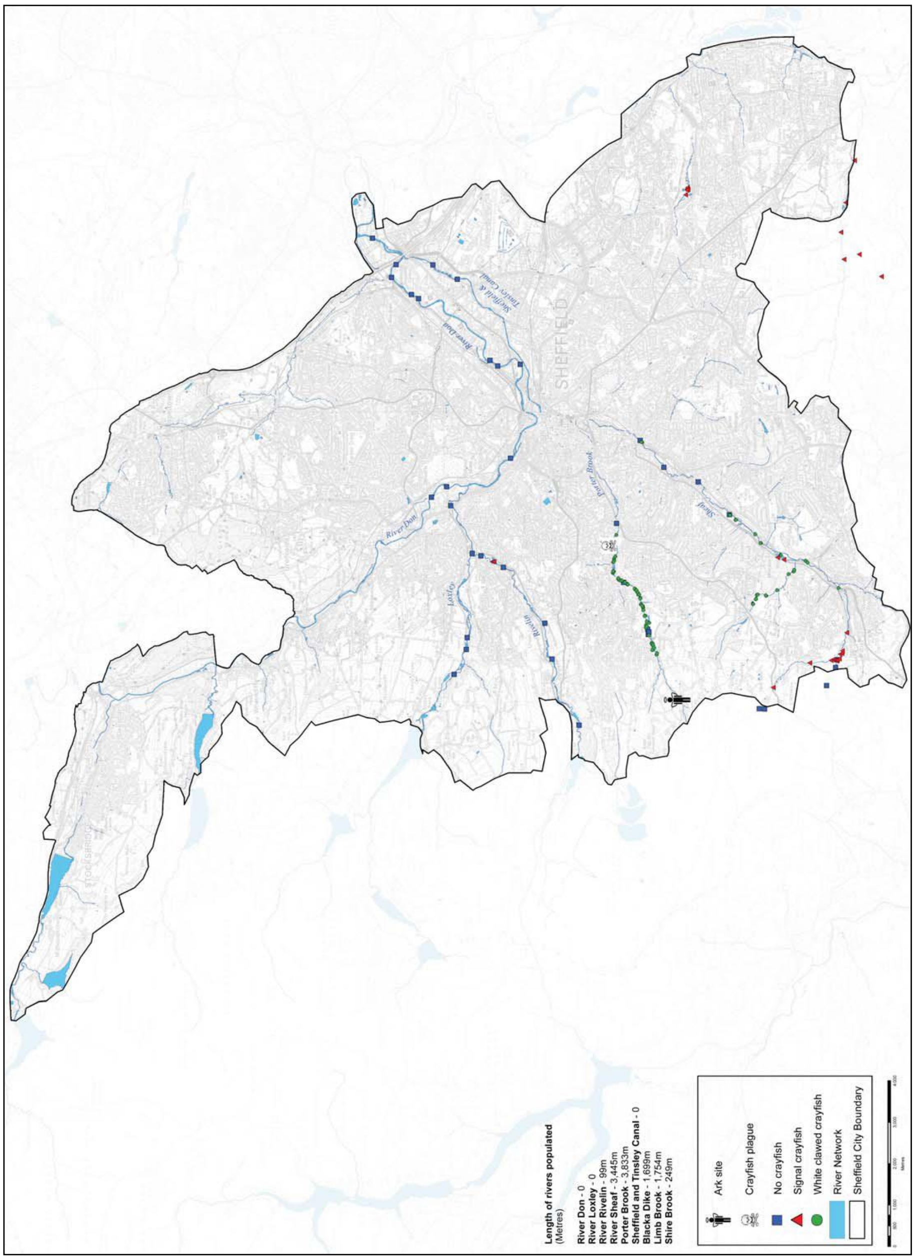

Figure 3. Map of previously known crayfish locations. Collated by Sheffield City Council, 2010

4.2. CURRENT DISTRIBUTION

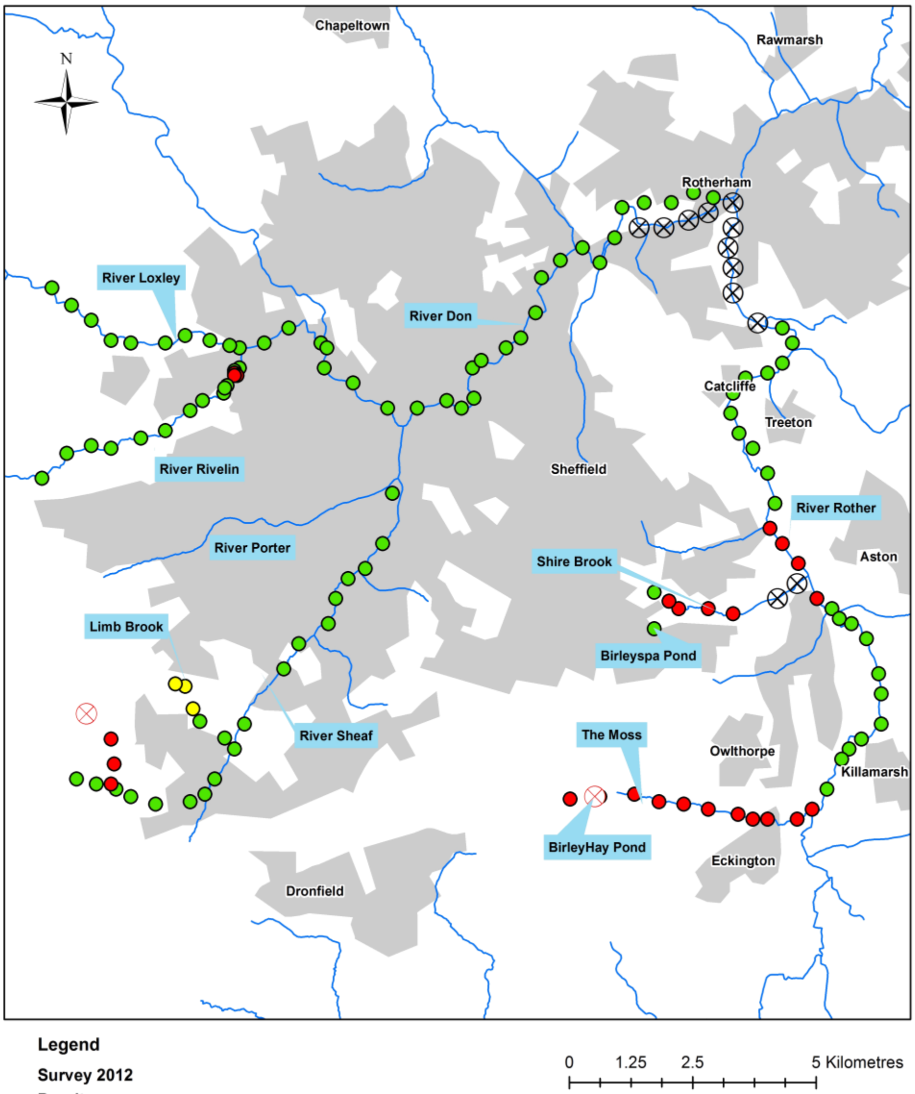

Figure 4. Map showing results of survey undertaken in 2012 within Don Catchment

The results from the survey undertaken in the summer of 2012 show little change from the locations previously known to support crayfish (**Figure 3**). Given the age of many of these populations, it is surprising to observe little or no expansion from their previous extents, and in each instance the observed distances were less than the conservative estimate of 1.5km per year derived from previous studies

[14][20][23]. Of the two populations that showed an expansion, the average downstream dispersal was 0.96km per year, and there was no observed upstream movement. It must be noted that in many cases only positive survey data are available for watercourses, there is very little information regarding sites that have previously been surveyed but that have not been found to support crayfish. The document in **Figure 3** produced by CAS is the only one with such information, but unfortunately does not have data regarding the River Rother. Each watercourse is looked at in deatail in the following section.

4.2.1. RIVER DON AND CANAL

Despite anecdotal evidence of signal crayfish found at the Salmon Pastures nature reserve, no crayfish of either species were detected between the confluence with the River Loxley (SK342894) and Blackburn Meadows nature reserve (SK403921). Between this point and the confluence with the River Rother no access was possible to the river, but no crayfish were found in the canal section.

4.2.2. RIVER ROTHER, SHIRE BROOK AND THE MOSS

Between Woodhouse Mill and the weir at Beighton (SK446842) a significant population of signal crayfish was discovered, occuring at every location surveyed at 500m intervals and at high densities. Only one site immediately below the weir produced negative findings, likely due to the faster current produced by the weir stream. It must also be noted that one of the traps at this site was removed by persons unknown, reducing the trapping effort. Upstream of the weir no crayfish were found on the River Rother. This is indicative of the Beighton weir presenting an insurmountable obstacle to the crayfish and providing an effective barrier against their spread. Due to the density of vegetation and distance of paths from the river banks, no access was possible to the River Rother between its confluence with the River Don (SK425923) and the M1 (SK436893). Between this point at the Woodhouse Mill regulator (SK432857) no crayfish were found, though a fisherman reported a sighting at Catcliffe Flash nature reserve (SK424880).

Image 4. A trap containing signal crayfish from the River Rivelin at Walkley Bank Tilt. Image from author's collection.

A single individual was also recorded immediately downstream of the confluence with the Moss Brook (SK441801). This is likely to be a recent extension of the Moss Brook population, and poses a serious threat as there are no barriers in the vicinity, but a large stretch of well vegetated, relatively slow moving channel that presents a viable habitat capable of sustaining a large new population of signal crayfish.

The Moss continues to support great numbers of signal crayfish, as has been recorded previously since 2005. Records from the 1990's show that native crayfish were also found here, but they have been absent for at least a decade. At every site between the mill pond at Birleyhay and the confluence with the River Rover, signal crayfish were found in vast quantities with a maximum of 35 individuals recorded at a single site. At one site a trap was also found to be damaged and empty of crayfish, though the adjacent trap contained many individuals. The author cannot say whether this trap was caused by a particularly aggressive signal crayfish, or some other animal such as a rat.

The population in the Moss Brook appears to have shown the second largest expansion of 2.4km (0.6km per year) downstream into the body of the River Rother. Extensive surveying in 2008 record the furthest downstream location on the Moss as SK421801, though there is no record of negative results further downstream from this. Given the estimate of 1.5km a year, the signal population could be expected to have dispersed 6km from this point by now, and so they could be expected to have reached the Rother Valley Country Park. This study found the actual extent to be just North of the Moss/Rother confluence SK441801.

Anecdotally, the mill pond is cited as the source of the introduction, and this is supported by the vast quantities of crayfish found downstream, compared to a single specimen found upstream from this location. Regrettably no data is available for the pond from this survey as permission was denied by landowners, however previous surveys have shown them to be present in the mill pond in large numbers.

The Shire Brook continues to be infested with signal crayfish at a high density between Carr Forge pond (SK413842) and the culvert under the A57 (SK425840). Previous reports from as early as 1995 (substantiated in 2005 and 2009) indicate that this population has been present for many years. No crayfish were recorded at the Western extent of the Shire Brook nature reserve (SK408845) during this study, and they have not previously been found at this location. However, this population has shown the largest downstream movement of any within the catchment, stretching 4km in 3 years (1.33km per year) into the River Rother where they have expanded both upstream and downstream to occupy the 1.7km strech of river between the Woodhouse regulator and the bridge under the A57 downstream of the weir at Beighton.

4.2.3. RIVER SHEAF, BLACKA DIKE AND THE LIMB BROOK

Though isolated records exist of the presence of both white-clawed (SK330824 – 2005) and signal (SK324819 – 2007) crayfish in the River Sheaf in the lower stretch