of the river, the 2012 survey found no cases of the native species. The signal population was focused upstream between SK299815 and SK300816 in Blacka Dike without exception. This was marked at its lowest extent by a small weir. Access to a potential site was denied by the landowner at Fern Glen Farm (SK293800) and so it is unknown whether the population extends this far upstream. The signal population on the River Sheaf/Blacka Dike around Totley has actually reduced spatially since the Yorkshire Wildlife Trust survey in 2009/10. At a conservative estimate of 1.5km a year expansion rate, this population could be predicted to have spread approximately 3km downstream into the channel of the River Sheaf by 2012, but instead was seen to have retracted by 0.7km. The population appears to be confined to Black Dike and no specimens were recorded in Totley Brook, where they were previously found. It cannot be stated with certainty that the population has truly receeded, as the possibility of obtaining false negatives from trapping exists.

The Limb Brook was found to still support native crayfish at numerous sites between the A625 (SK311826) and Eccleshall Wood (SK316821), at increasing densities upstream. No signal crayfish were found at any point along the stream, and with no historic record of their presence here. This suggests that they pose no immediate threat to the population of white-claws residing there.

4.2.4. RIVER RIVELIN

A single site was found to contain signal crayfish on the Rivelin, at the stretch of river adjacent to Walkley Bank Tilt (SK323888). At 500m resolution, no crayfish were found either upstream or downstream of this location, suggesting that the population is concentrated within a narrow geographic range. To test this hypothesis, the stretch of river was re-surveyed at a finer resolution of 100m. This found the population to be limited to a 300m segment that was directly adjacent to the fishing pond, which also contained signal crayfish. Due to the popularity of the pond amongst local fisherman, the author considers it likely that this is the origin of

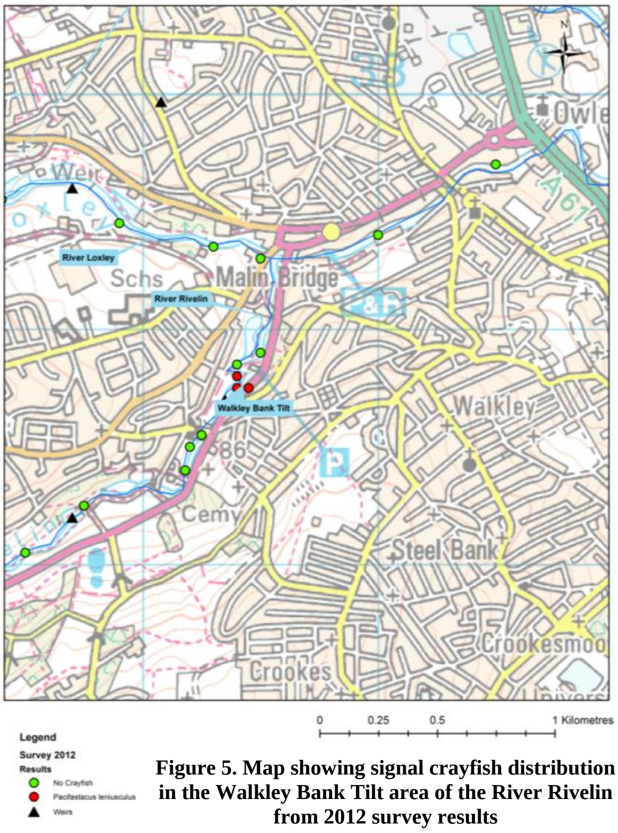

Figure 5. Map showing signal crayfish distribution in the Walkley Bank Tilt area of the River Rivelin from 2012 survey results

this infestation. The distance between the pond and the river channel is <10m in places, and so the crayfish would have little trouble in travelling between the two bodies. Whether they were introduced directly as bait or a source of aquaculture, or via improperly cleaned equipment carrying eggs or larvae cannot be determined. As there is only a single record of signal crayfish previously in this location from 2009/10 (**Figure 3**), it is highly likely that this is a very recent infestation that potentially could expand a long way beyond its current limits. The historical exploitation of the River Rivelin for industry has created a network of slow moving, deep, secondary channels and ponds along its course which could provide ideal habitat for signal crayfish. It is the authors opinion that this population should be monitored carefully in the future, as the newest, smallest and most isolated of the signal crayfish populations in the catchment it could provide both the best study conditions and the best opportunity to intervene in their movements.

4.2.5. RIVER LOXLEY

The River loxley was found to be completely free of both signal and native crayfish between its confluence with the River Rivelin (SK324893) and the Damflask reservoir (SK287906). Trapping at 500m intervals found no trace of crayfish and there are no historic records of any incidences. Similarily no anecdotal evidence was found to suggest the presence of either species on this watercourse.

4.3. CATCH PER UNIT EFFORT AND SIZE

Whilst the size bias incurred by crayfish trapping negates its reliability in accurately estimated population densities [49], catch per unit effort (CPUE) is still useful in comparing the relative abundances of populations. Catch rates were found to be highest in the Moss Brook reaching 35 individuals at a single site and an average of 16.8 per site. Evidence of this population date back as far as 1995, whilst sites with lower catch rates such as Blacka Dike and the River Rivelin, have only been recorded recently, in the 2009/10 Sheffield Wildlife Trust survey with average catch per site rates of 4 and 6 respectively. The second highest catch rates of 7 individuals average per site were found in the Shire Brook, where data exists to confirm their presence since 2005. From this information, it is possible to infer that catch per unit effort is linked to the age of the population. Unfortunately, no historical data are available for the River Rother (either of previously recorded populations or negative survey results), however the lowest average catch rate of 2.8 individuals per site was found on this river. By plotting the date when crayfish were first recorded against the average CPUE of a waterway, a linear trend was found and the approximate age of a population extrapolated for a given CPUE (**Figure 6**). In this way, the date/density relationship for the River Rother suggests it was infested sometime during 2011, which would tally with the theory that it is the result of expansions of the older populations found in the Shire and Moss Brooks. It would also explain why there are no older records of signal crayfish in the river.

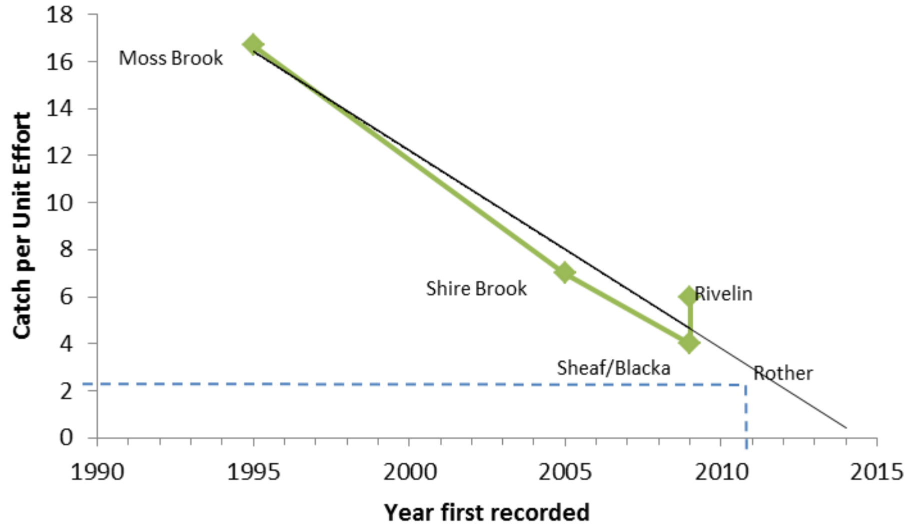

Figure 6. Scattergraph showing CPUE against first record of crayfish for each waterway in the Don catchment survey. A linear trendline (Black line) allows the approximate age of a population to be calculated from CPUE (Dashed line). For the River Rother, a CPUE of 2.8 dates the population as having infested the river in 2011.

Previous studies have demonstrated that the size of crayfish at a site is linked to the depth of water [57] with larger, adult individuals inhabiting deeper pools, whilst smaller or juvenile crayfish show a preference for riffles [58]. This could be due to a number of reasons. Pools have been shown to contain greater numbers of invertebrates [59] which could thus support larger crayfish. Predation by fish is more likely in deeper, slower water and so smaller crayfish more susceptible may migrate from them or be consumed. The slower flow rates in pools also leads to a finer substrate being deposited than in riffles which may have some significance. Signal crayfish captured in this study were observed to have larger average body sizes in the main river channels of the Rother and the Rivelin, than in the smaller Moss and Shire Brooks and the Black Dike. Where possible, traps were placed in deeper pools (often the outside of bends) within the smaller watercourses to ensure the minumun required depth of 60cm was achieved (**Table 1.**), but depth was seen to vary greatly, often reduced to <10cm over riffles. In contrast, the larger Rother and Rivelin Rivers provided a more homogenous environment with consistently greater depths. These data are summarised in **Table 2**. Using SSPS[3], the relationship between average depth of site and average length of crayfish captured for each waterbody was explored. A Pearson correlation coefficient of 0.954 was achieved at a P value of 0.01, satisfying the criteria of high statistical significance of the relationship between the two variables. Each site was entered individually, rather than averages for each watercourse, to increase the sample size and allow a more robust analysis (**Appendix D**).

[3] http://www-01.ibm.com/software/analytics/spss/ (Accessed 15th August 2012)

Table 2. Average depth of sites for each waterway surveyed, with average size of crayfish recorded and maximum individual size.

Waterbody	Average depth of site (M)	Average Size (cm)	Maximum size (cm)
Rother	2.4	14.8	18
Rivelin	1.6	9.7	15
Sheaf/Blacka Dike	0.8	6.3	7
Shire Brook	1	6.1	9.5
Moss Brook	1.2	7.5	11

4.4. ENVIRONMENTAL VARIABLES

4.4.1. VEGETATION

123 sites were sampled during this study, of which 26 were found to contain signal crayfish and 3 containing native white-clawed crayfish. Each site was classified into one of three categories depending on the predominant landuse. These were urban (heavily industrialised with mostly concrete lining the waterway and often subjected to extensive channelisation), woodland and grassland. The Rivers Don and Sheaf largely fell into the urban category, whilst the River Rother was observed to run through grassland for most of the study area. The Rivers Rivelin and Loxley, Blacka Dike and the Limb, Shire and Moss Brooks were all classed as woodland habitats.

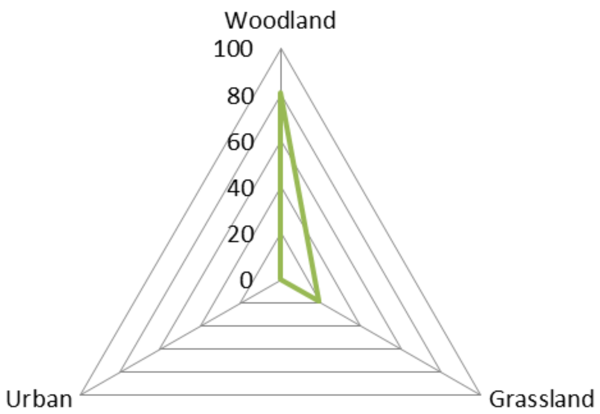

Figure 7. % of sites where signal crayfish were found for different land uses. A clear preference can be observed for woodland river systems

Figure 7 shows the distribution of crayfish (both species) sites amongst these various habitats, and it is immediately apparent that the majority of sites fall into the woodland r iver systems (urban - 0; grassland – 5; woodland – 21).

Previous studies have identified the presence of riparian vegetation as a key factor in determining the suitability of a site for crayfish in providing both shade and refuges [40]. The findings from this study support this theory, particularly as many sites recorded as grassland still contain sparsely distributed trees along the bank. This may also explain why distribution rates observed in this study were lower than predicted, as the expanding populations were leaving favourable woodland river conditions found on the Shire and Moss Brooks and entering the more open grassland conditions of the River Rother. Livestock was observed to be grazing on much of the grassland adjacent to the River Rother, which has been linked to increased sediment and chemical in the river channel producing unsuitable conditions for crayfish [37]. All urban sites were found to be free of crayfish, potentially due to the impenetrable nature and relatively few refuges afforded by concrete lined channels. Where the river did flow through natural channels, vegetation was observed to be much sparser than found in either woodland or grassland systems. Due to the high level of anthropogenic interference, it is very difficult to assess the true value of these habitat characteristics in determining suitable habitat for signal crayfish. Whilst patterns as described above are discernible, they may be due to human preference for discrete and/or aesthetically pleasing environments. For example, heavily wooded sections of river channel will provide more cover and privacy in which to harvest introduced crayfish populations for wild food.

4.4.2. WEIRS

Figure 8 shows the locations of weirs (and locks on the canal) within the catchment and in relation to survey sites where crayfish were found. The River Sheaf and River Don can be seen to be heavily developed in this respect, with large numbers of obstructions over short distances. The River Rother, Moss and Shire Brook are all seen to be relatively unobstructed in this respect. It is difficult to gauge the role that obstructions such as these play in limiting the dispersal of crayfish, as many of the populations are small and occur in areas where there are few if any barriers. However, there are a few sites where weirs do seem to have imposed some degree of control over their movements. Most pronounced of these is the River Rother North of the village of Beighton. Here a healthy population of signal crayfish is bracketed

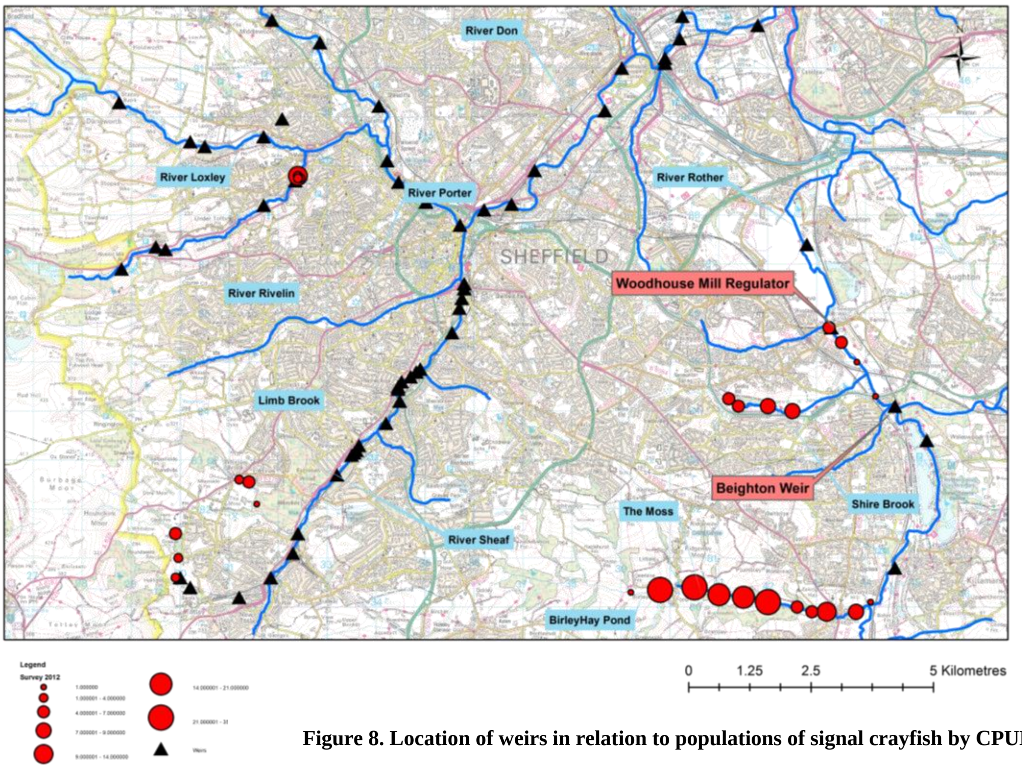

Figure 8. Location of weirs in relation to populations of signal crayfish by CPUE

neatly by the Woodhouse Mill regulator at its Northern extent, and the Beighton weir at its Southern extreme. Weirs can also be seen on the River Rivelin immediately upstream of the signal crayfish infestation, though due to the limited spatial distribution of this population and its believed recent introduction, it is not thought that this weir has influenced the distribution at this time. There is a large volume of unoccupied territory downstream that would provide equally favourable conditions to accomodate the expansion that is likely to ensue. However, this weir may prove useful in protecting the upstream river once the signal population is more established. Downstream of the population in Blacka Dike is a small weir that marks the limit of their current distribution. Historical records show that signal crayfish have previously been present downstream of this obstruction, and so it is doubtful that it is effective in blocking their passage. It is unknown if this population was introduced up or downstream from the weir. They are well established upstream in Blacka Dike, and landowners on a farm refused to allow surveying on their land. This could be interpereted as an indication that they had introduced the species to the stream running through their property, and wished this to be unknown. However, isolated records of signal crayfish further down the River Sheaf that could indicate otherwise. Previous studies regarding movement of crayfish have focussed on river sections free from obstruction, being primarily concerned with the size of individuals and their direction and distances travelled [16][20]. The ambiguity of the efficacy of weirs as barriers to crayfish found in this study highlights the importance of researching this relationship further. As stressed previously, whilst a signal population cannot realistically be eradicated, influencing its dispersal and being able to ensure certain river stretches will be un-infested is of paramount conservation concern.

4.4.3. GEOLOGY AND WATER QUALITY

As noted in the introductory section of this report, crayfish have been associated with high levels of calcium which is required for the development of exoskeletons [35]. This is often found in limestone river catchments which also support high levels of invertebrates and so would provide ample food sources for crayfish. The rivers of the Don catchment, however, rise in the millstone grit of the peak district national park [60] and flow through bands of sandstone, mudstone and gritstone (**Figure 8.**). A region of magnesian limestone is reached further to the West, but falls outside of the study area. The presence of crayfish despite the non-calcareous nature of the bedrock suggests that either this is not a defining habitat requirement of the species, or that the water is enriched with calcium from another source. Given the high level of industrial activity [60] in the area this is a possibility though no data regarding water quality could be obtained for analysis in this study. It can be observed that rivers close to the industrial centres of Sheffield (notably the River Don and lower reaches of the River Sheaf) are free from infestation of signal crayfish. Whether this is due to the reduced water quality resulting from industry and sewage discharges, channelisation of the river removing refuges or any other factor (or indeed combination thereof) cannot be determined from the information currently available.