Report and health check of the river Crane/Moors with specific emphasis on management for the Odonata

Bournemouth University SERT (Student Environment Research Team 2016

Clemency Carroll, Olive Haigh, Luke Anning, Lucia Parker, and Rachel Richards and Dr Elizabeth Franklin

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Summary

The presence of Odonata (dragonflies and damselflies) on the Moors River system at Moors Valley Park is one of the reasons that it gained SSSI (Sight of Significant Scientific Interest) recognition in 1999. The dragonflies and damselflies present at Moors Valley utilize the riverine system, lakes and ponds as their habitat. Moors Valley Park is a much loved public amenity and as such is required to balance the needs of the public and the requirements of being a SSSI.

This report is a review of historical chemical and biological surveys of water quality in the Crane/Moors River system adjacent to Moors Valley Park and a river habitat survey within the park to identify the quality of the riverine habitat for dragonflies and damselflies.

The results from the historical data show that the Crane/Moors river (up to 2009) was in natural or near natural biological and chemical state having improved from the 1990's. The invertebrate siltation index supports reports of the area upstream of Moors Valley Park having had an increase in siltation. However, downstream of Moors Valley Park has shown an increase in siltation intolerant invertebrates indicating decreased siltation up to 2009. This suggests, that at least up to 2009, Moors Valley Park was not contributing to siltation downstream of the park. The results of the student led survey indicated the presence of a good level of emergent and amphibious vegetation and a sandy, pebbled river bed over most of the stretch of the Crane/Moors through Moors Valley Park which is excellent for dragonfly and damselfly lifecycles; for emerging nymphs and resting adults.

From the surveys channel shading and siltation were identified in some areas as possibly reducing habitat suitability for dragonflies and damselflies.

Further work would include linking historical biological and chemical data with dredging events at Moors Valley Park and up to date biological and chemical pollution sampling.

Acknowledgements

We would like to thank Claire Gronow and Sara Tschersich for support at Moors Valley Park and providing information and access. Keith Powrie for his expert introduction to damselfly and dragonfly identification and access to his historical records and Josie Pegg for her training in River habitat surveys.

Contents

Site Details and Project Introduction

Moors Valley Park encompasses a section of the Crane/Moors River, which has had SSSI recognition since 1999[1] . The SSSI notice states that the *"Moors River and associated water features are notable for an outstanding dragonfly fauna"*[1] which has led Moors Valley Park to adopt the dragonfly as its symbol. Moors Valley Park was founded in 1984, opening officially in 1988 with artificially created lakes and redirected watercourses[2]. It houses a golf course, playgrounds and a miniature railway along with cycle and walking routes. As such, it needs to strike a balance between supporting the important fauna and flora that live there and serving the public. The Environment Agency describe the Moors river system at Moors Valley Park as *"situated at the point where the river loses its chalk stream character and becomes the Moors River proper, is an extremely well-used public amenity…"*[3]. In 2009 the SSSI Condition Assessment it was indicated that the upper section of the Moors river system had a high level of silt deposition (40-50%) much higher than the recommended 10% for conservation[4] and as such, requiring improvement.

It is in light of the valuable fauna, public use and unfavourable siltation of upper reaches of the Moors River that the SERT (Student Environment Research Team) from Bournemouth University have engaged with Moors Valley Park to review historical data and conduct up to date surveys on the Moors River section through the park (Fig 1). This is the report on the health of the river with specific emphasis on management for the Odonata from the review and surveys.

Fig 1. Map of the stretch of Moors River covered by the SERT team

[1] http://www.sssi.naturalengland.org.uk/citation/citation_photo/1004461.pdf
[2] http://www.moors-valley.co.uk/visitor-information/history-of-moors-valley/
[3] Environment agency 2012, The lower Stour and Moors River- Broad ecological Vision and Restoration Measures Hyder Consulting (UK) Limited.
[4] Natural England, (2009) Conservation Objectives, for the Moors River System SSSI

Methods

River habitat survey

The river habitat survey (RHS) is a standard survey used by the Environment Agency to get an overview of a river section including vegetation structure, habitat context and geomorphological influences. Observations are taken every 50m along a 500m stretch of river including bank type, vegetation structure, channel blockages, flow type and photographs. The blank (RHS) form has been included in the appendix i.[5] The student team carried out this assessment for the River Crane in the first two weeks of June 2016 starting at the following downstream locations:
Above Ebblake (Downstream start Easting: 410537 Northing: 106570),
After Ebblake (Downstream start Easting: 410307 Northing: 106107),
Lower Crane (Downstream start Easting: 410508 Northing: 105622) and
Ebblake stream (Downstream start Easting: 410552 Northing: 106516).

Historical data

Historical data provided by Moors Valley Park and available on the Environment agency.gov.uk webpage was used to provide an analysis of the historical change in biological and chemical pollution at the site from 1990 – 2010 [6] [7](Appendix ii & iii).

Water quality

Water quality information was collected from historical data on water quality on environmentagency.gov.uk from 1990 to 2009[6] [7] (Appendix iii). The two sites closest to Moors Valley Park are the upstream Squirrels Corner-Romford (Crane Sampling Fig 2) Easting:403300, Northing:115200 - Easting:407500, Northing:109000 and the downstream Conf With Crane-Palmersford Stw (Moors Sampling Fig 2) Easting:409500, Northing:101200 - Easting:410400, Northing:100600.

[5] Environment Agency (2003) River Habitat Survey in Britain and Ireland: River Habitat Survey Manual: 2003 version
[6] http://maps.environment-agency.gov.uk/wiyby/wiybyController?latest=true&topic=riverquality&ep=query&lang=_e&x=407457.73958333343&y=108992.12499999945&scale=6&layerGroups=2&queryWindowWidth=25&queryWindowHeight=25
[7] http://maps.environment-agency.gov.uk/wiyby/wiybyController?latest=true&topic=riverquality&ep=query&lang=_e&x=410434.5520833333&y=100624.3125&scale=6&layerGroups=2&queryWindowWidth=25&queryWindowHeight=25

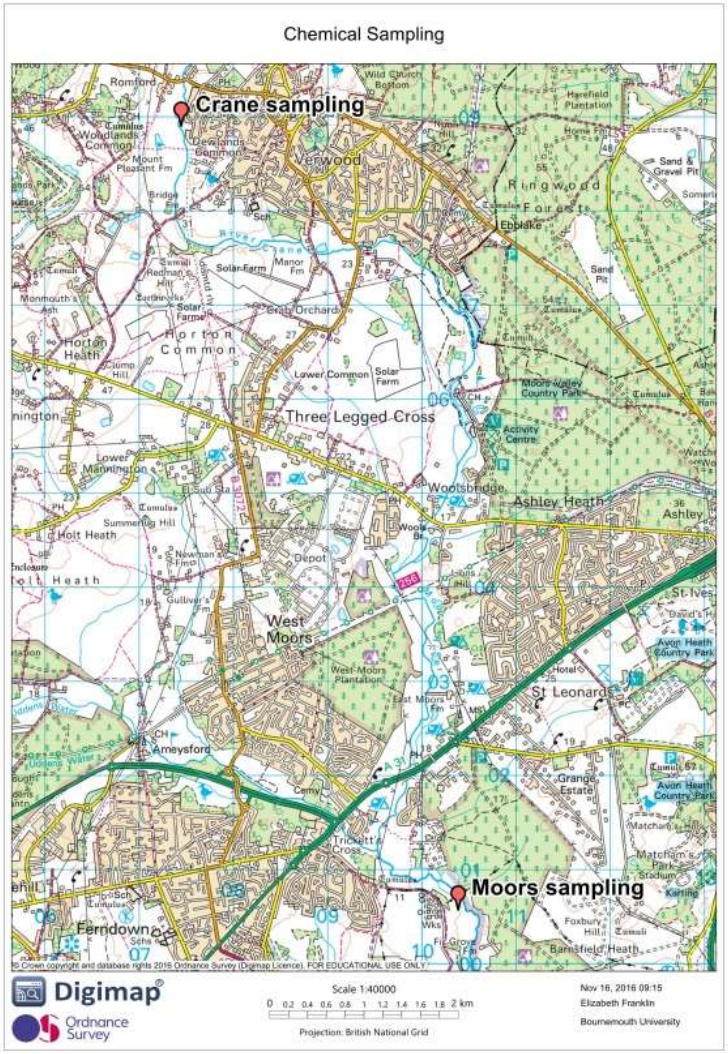

Fig 2. Locations of historical chemical data sampling Squirrels Corner-Romford (Crane Sampling) and Conf With Crane-Palmersford Stw (Moors Sampling) in respect to moors valley park.

Invertebrate kick sampling and BMWP Score

Invertebrate family presence or absence is a reliable way of assessing the pollution status of a watercourse. This is because point chemical sampling can miss pollution events like runoff after flooding or spills. The invertebrates live there all the time and if a family is killed due to a pollution event, then they are going to be absent from the population for a while before returning, allowing for the assessment of water quality.

Invertebrates are then identified to family and the presence or absence of each family noted. Of 84 families, each family has a pollution score from 1 -10. 1 being very tolerant and 10 being very sensitive to pollution. The BMWP score is the sum of all these tolerances found in a sample. This is then standardised by dividing by the number of families present giving the average score per taxon or (ASPT). This is then used as an indicator of river pollution levels.[8] With the data provided by Moors valley park and the environment agency [6] [7] (Appendix ii) the biological trend in water quality has been

[8] Wright JF et al. (2000)Assessing the biological quality of freshwaters: RIVPACS and Other Techniques- Freshwater Biological Association

plotted from 3 sites in the moors valley area. Crane (SU-09300-07600), Moors 1 (SU-10100-04700) and Moors 4(SU-09800-03800) Fig 3.

The kick samples were conducted with a standard kick sampling net (25cm square x 20cm deep). The net is placed downstream of the sampler and the river bed above the net is kicked, catching disturbed invertebrates in the net. This is conducted for 3 minutes

Invertebrate kick samples PSI sedimentation index

River sedimentation can greatly affect the biodiversity of the watercourse[9]. Again different taxa have different sediment tolerances[9]. To assess the PSI sedimentation index a score was given to a stream depending on the taxa present from the invertebrates caught a the kick sample.

With the data provided by Moors valley park (Appendix ii) and the Environment Agency [6 7] the trend in sedimentation has been plotted from 3 sites in the moors valley area. Crane (SU-09300-07600), Moors 1 (SU-10100-04700) and Moors 4(SU-09800-03800) Fig 3.

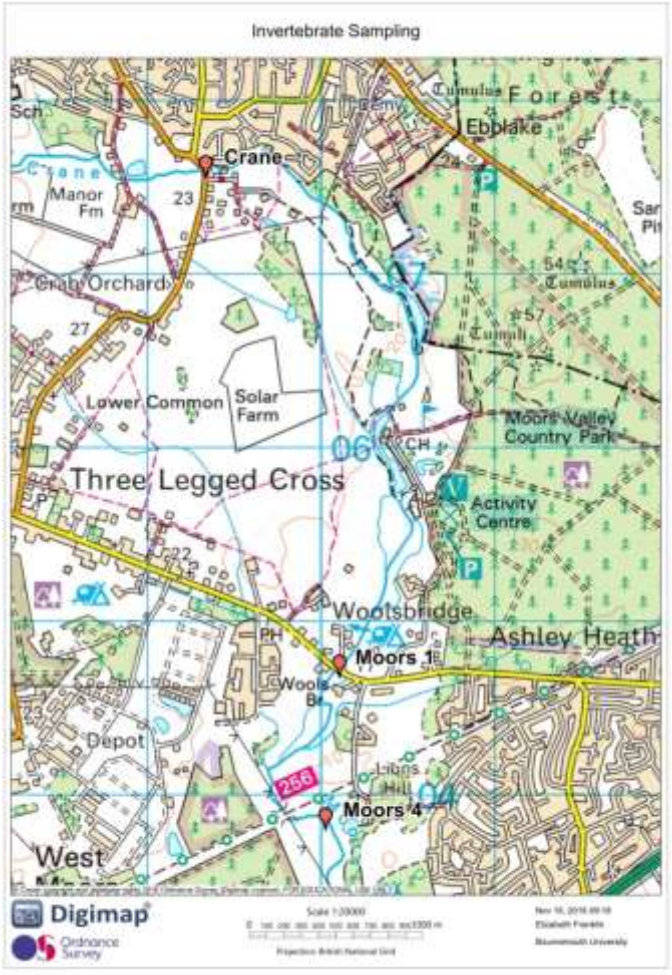

Fig 3. Locations of historical invertebrate sampling Crane (SU-09300-07600), Moors 1 (SU-10100-04700) and Moors 4(SU-09800-03800).

[9] A Extence C, P Chadd R, England J, J Dumbar M, J wood P, D Taylor E. The assessment of fine sediment accumulation in rivers ising macro-invertebrate community response. River Research and Applications. 2013 Jan 1;29(1):17-55.

Results from the Historical Data

Biological pollution assessment

The average score per taxon, biological pollution scores for the Crane, Moors 1 and Moors 4 have improved from 1990 – 2010. The crane site (SU-09300-07600, Fig 3) has significantly improved from a poor state to a moderate state (Pearson rho 0.776 significance <0.001, Fig 4). The Moors 1 site (SU-10100-04700, Fig 3) has significantly improved from a poor state to a good state (Pearson rho 0.749 significance <0.001, Fig 4). The Moors 4 site (SU-09800-03800, Fig 3) has significantly improved from a very poor state to a moderate state (Pearson rho 0.926 significance <0.001, Fig 4).

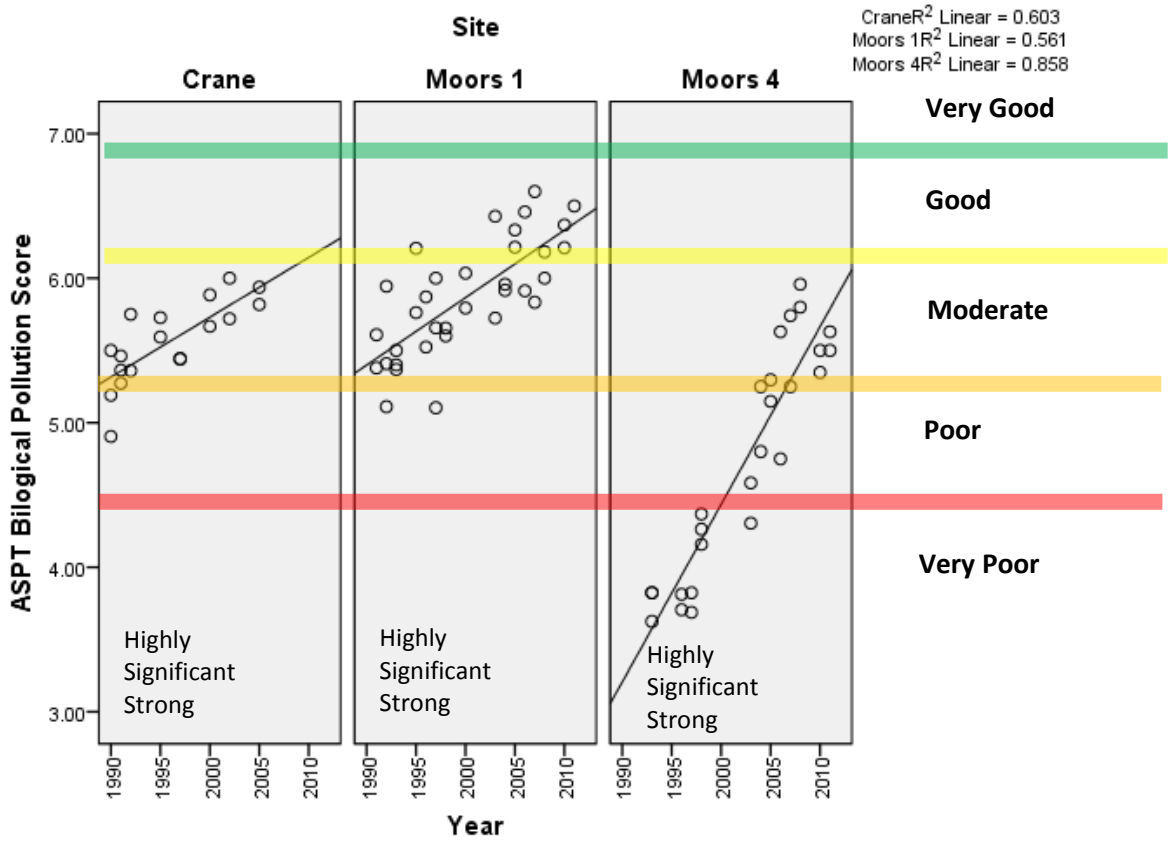

Fig 4. The change over time in the average score per taxon biological pollution score for the Crane (SU-09300-07600), Moors 1 (SU-10100-04700) and Moors 4(SU-09800-03800). Lines show regression lines and overall trend in biological pollution score.

Biological sedimentation assessment

The average biological sedimentation score for the Moors 1 and Moors 4 have improved from 1990 – 2010 where at the Crane site the sedimentation score has increased. The Crane site (SU-09300-07600, Fig 3) has significantly decreased from a moderately sedimented state to a heavily sedimented state (Pearson rho -0.550 significance 0.018, Fig 5). The Moors 1 site (SU-10100-04700, Fig 3) has significantly improved from a moderately sedimented state to a slightly sedimented state

(Pearson rho 0.405 significance 0.017, Fig 5). The Moors 4 site (SU-09800-03800, Fig 3) has significantly improved from a heavily sedimented state to a slightly sedimented state (Pearson rho 0.903 significance <0.001, Fig 5)[10].

This study supports the findings of the 2009 SSSI Condition report[4] suggesting that the increased siltation in the upper Crane is changing the river biota above Moors Valley Park at the Crane Site. As the data shows a significant decline of PSI sedimentation score (Fig 5).

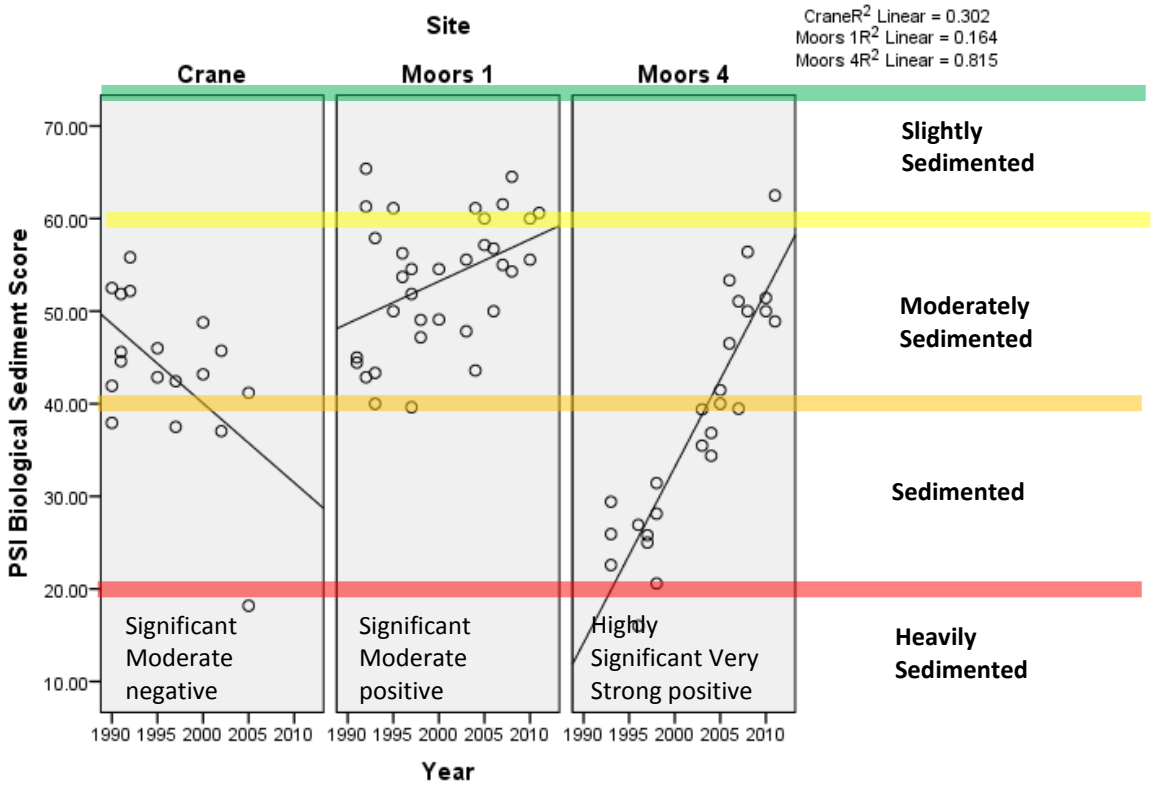

Fig 5. The change over time in the PSI Biological sedimentation score for the Crane (SU-09300-07600), Moors 1 (SU-10100-04700) and Moors 4(SU-09800-03800). Lines show regression lines and overall trend in biological sedimentation score.

Chemical pollution assessment

The Crane (Squirrels Corner-Romford) site has shown a significant decrease in ammonia from 1990 to 2009 (Pearsons rho -0.592, significance 0.01, Fig 6). However the level of dissolved oxygen had not significantly changed over this time period (Pearsons rho 0.261, significance 0.295, Fig 7). The Moors (Conf With Crane-Palmersford Stw) site has shown a significant decrease in ammonia from 1990 to 2010 (Pearsons rho -0.674, significance 0.002, Fig 8). However the level of dissolved oxygen had not significantly changed over from 1993-2009 (Pearsons rho -0.310, significance 0.226, Fig 9).

[10] http://www.riverhabitatsurvey.org/Documents/ToolHabManual1-3/ToolHab.html?400222.html

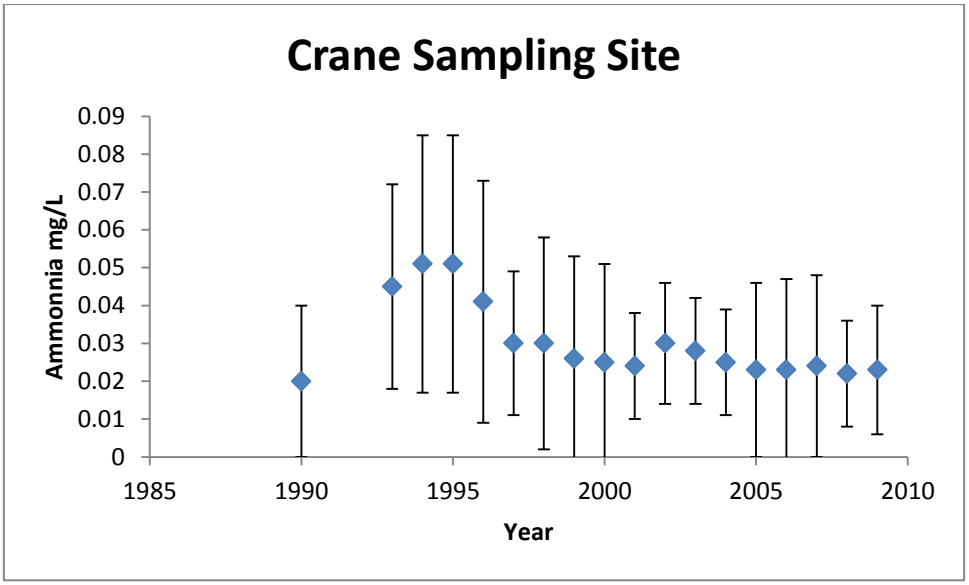

Fig 6. The mean (diamonds) and standard deviation (whiskers) of the mean ammonia levels in mg/L at the Crane (Squirrels Corner-Romford) site

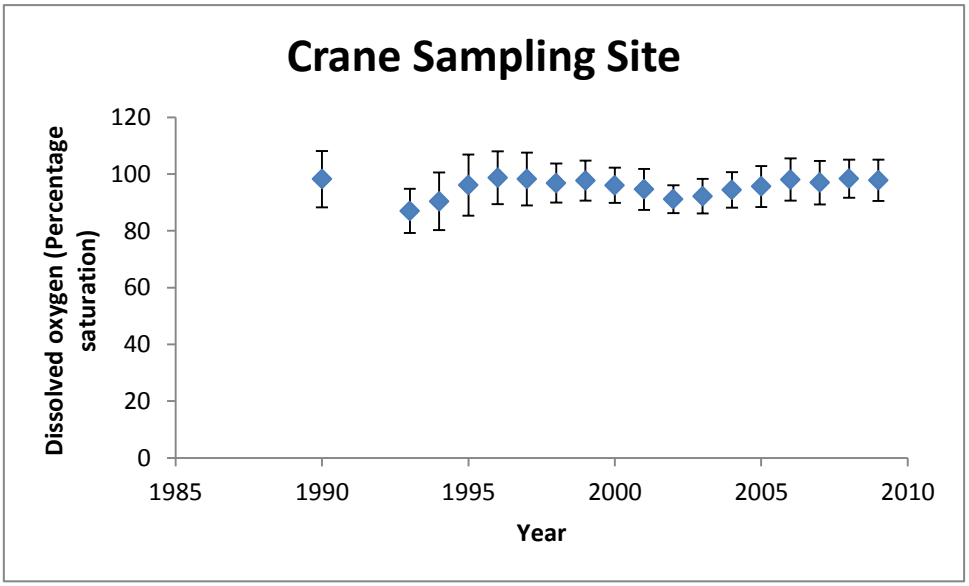

Fig 7. The mean (diamonds) and standard deviation (whiskers) of the mean percentage oxygen saturation within the water at the Crane (Squirrels Corner-Romford) site

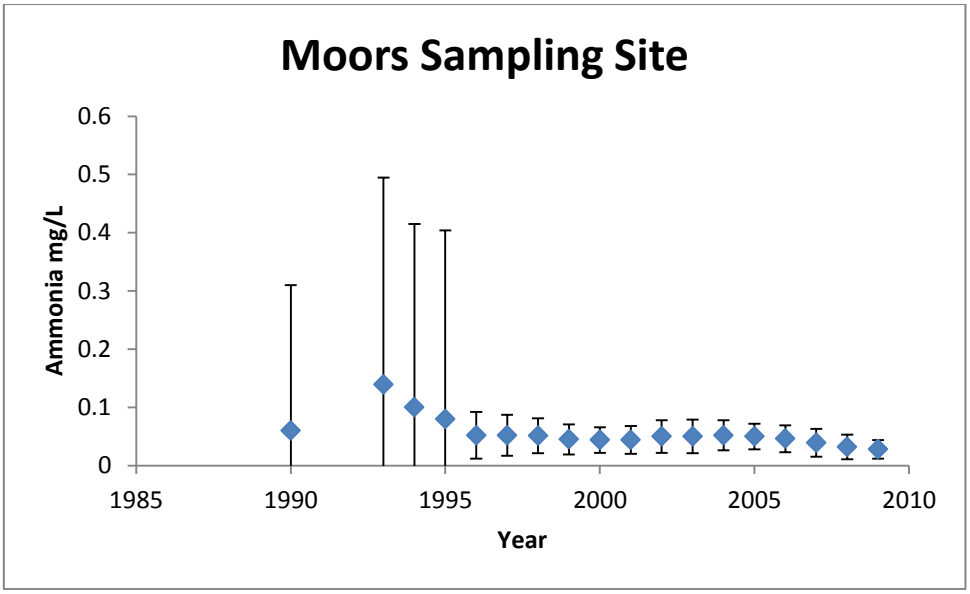

Fig 8. The mean (diamonds) and standard deviation (whiskers) of the mean ammonia levels in mg/L at the Moors (Conf With Crane-Palmersford Stw) site

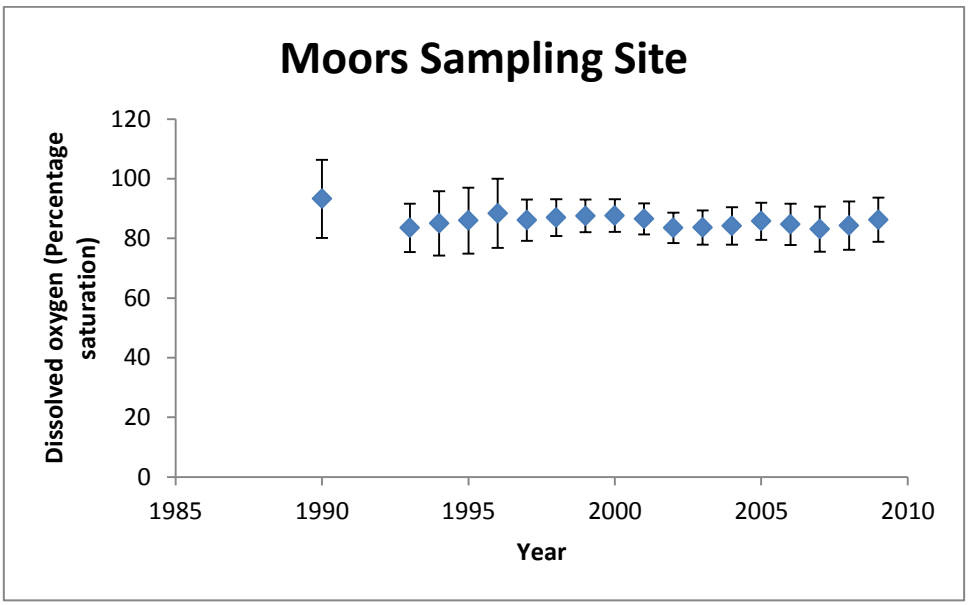

Fig 9. The mean (diamonds) and standard deviation (whiskers) of the mean percentage oxygen saturation within the water at the Moors (Conf With Crane-Palmersford Stw) site

Site overviews (surveyed and written by student team)

Student surveying team: Clemency Carroll, Olive Haigh, Luke Anning, Lucia Parker, and Rachel Richards.

River Crane/Moors Above Ebblake stream

(Downstream start Easting: 410537 Northing: 106570)
Date of Survey: 10/06/16
Author: Olive Haigh

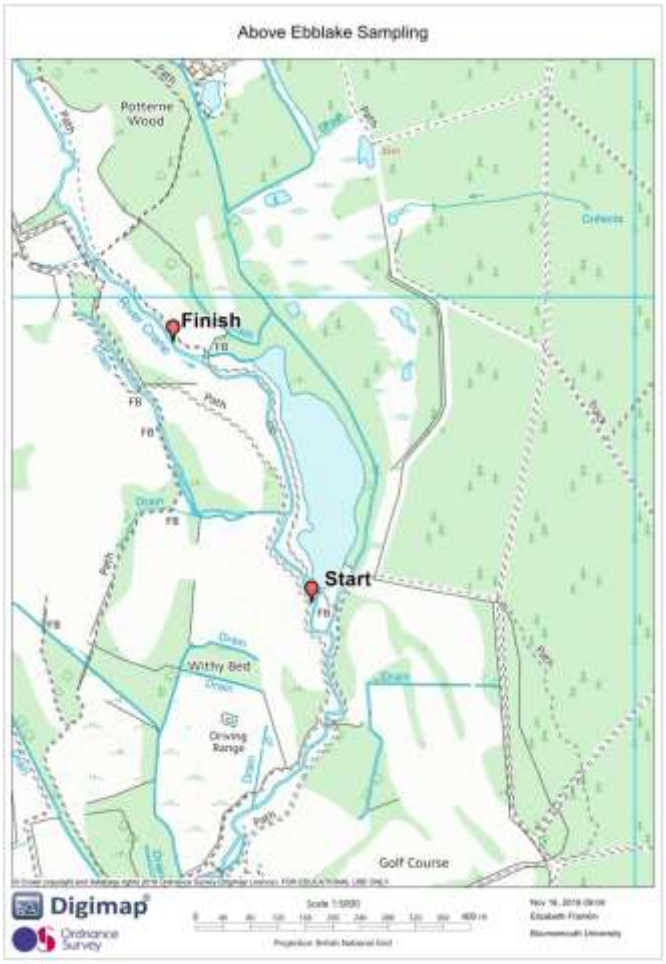

Fig 10. Above Ebblake survey stretch starting at downstream point

Physical attributes of the river site

This river was surveyed from the left and right bank faces. For all ten surveyed points along the river, the left and right bank materials were classified as earth. No bank modifications were seen or if any were not known. Point six and ten of the survey were the only not known areas. Marginal and bank features were predominantly classified under none, not visible or vegetated sidebars, which were seen at points three, six, nine and ten on the left bank and points nine and ten on the right.

The channel substrate changed quite consistently as the survey continued downstream, however at certain points the substrate was not visible. The substrate was mainly sand and was seen at site one, two, four and ten, indicating presence throughout the whole area from start, to middle to end. Where the substrate could be seen, frequent gravel and pebble was within the sand. At site six even bedrock was present but only in a small amount.

The flow type stayed as smooth but at site nine and ten further downstream, ripples were seen. No channel modifications or features were seen.

In summary the river physical attributes are as follows:

- Left and right bank material is earth
- No obvious bank modifications or features other than occasional vegetated sidebars
- Predominant channel substrate is sand with frequent gravel and pebbles. The rare presence of bedrock
- No obvious channel modifications or features
- Flow type smooth with occasional ripples

500m sweep up of the site

Land use within 50m of the river banks is scrub and shrubs. Rough unimproved grassland also and natural open water on the right. This is a lake seen at point one of the survey.

The bank profile is classified as steep >45 degree angle on both banks sides.

Bed material is consolidated.

On the left bank side, trees were continuous and regularly spaced but on the right they were isolated and scattered with occasional clumps, which were semi-continuous. Shading of the channel was present. Overhanging boughs, exposed tree roots, underwater roots and large woody debris was classified as more than or equal to 33%.

33% or more of the channel is choked with vegetation. Evidence of recent management is weed cutting.

Bank top land use and vegetation structure at the site

The vegetation types on the left and right banks were simple and complex.

Left bank top was all complex, showing four or more vegetation types other than at point three which was simple, with only two or three different types. The right bank top was complex except point one which was simple.

The left and right bank faces both started as simple up until point six, where they both became complex.

Channel vegetation type was quite diverse at particular points or certain features were not visible. All vegetation types on the survey were seen throughout the 500m area. These included emergent vegetation (reeds, grasses, herbs ect), submerged (broad, linear and fine leaved) and filamentous algae. All points along the survey had the majority of these vegetation types within them. The four most common seen every point were emergent, rooted floating leaved, amphibious and submerged fine leaved vegetation.

In summary, the vegetation structure is as follows:

- Complex vegetation type is dominant on both bank faces
- Vegetation types were diverse throughout the survey and the most common were emergent, rooted floated leaved, amphibious and submerged fine leaved
- Land use is scrub and shrubs and/or rough unimproved grassland within 50m of both banks
- Left bank side has continuous, evenly spaced trees, right has clumped semi-continuous
- ≥33% of channel is choked with vegetation

Fauna

Throughout this survey of the river it is worth noting the species that were seen. The Azure Damselfly was seen three times, flying in the shade. The Large Red Damselfly was seen once flying in the shade and resting on channel vegetation. The Beautiful Damoiselle was seen six times either flying or resting in the shade.

Dragonfly and Damselfly requirements

Although dragonflies and damselfly's belong to the same order called Odonata, they are in fact two separate species and have distinctive qualities. The damselfly is smaller and more delicate than the larger and stronger dragonfly. They therefore, also have different habitat requirements[11]. However, in general there are basic requirements that cover all species. Water must be clean and unpolluted, trees and scrubs are important on the banks of rivers to provide roosting areas from strong winds and predators, such as wagtail birds. Grasses of varying lengths around a habitat provide mating and feeding grounds, whilst submerged, emergent and floating vegetation provides ideal egg laying sites. Areas that provide sunlight are also preferred[11].

Focusing on requirements in general, I would say that the river above Ebblake stream at Moors Valley is providing good requirements, supported by the fact fauna was seen. There is complex vegetation on the river banks to provide mating and feeding grounds, varying vegetation types to provide egg sites and resting areas. The shrub around the area and trees provide shelter sites. However, due to the high level of trees on both bank sides, especially the left side meant that areas were more shaded than sunny. This may be a deterrent for dragonflies and damselfly's. Perhaps focusing on the areas that do receive more sunlight, those on the right side would be beneficial. Ensuring there is adequate vegetation and shelter maintained at the correct level. A simple case of grass cutting if necessary or replenishing plants if required. Other than this factor I cannot see any other problems for the species.

However some species are more specialised, for example like those as follows:

Beautiful demoiselle

This species is predominantly found along slow flowing streams and rivers that have sand or gravel substrates. Males like to rest of bankside vegetation in wait for females[12].

From what was outlined previously, it is no surprise that the Beautiful demoiselle was seen the most frequently whilst surveying. The river above Ebblake stream has slow flowing water, complex vegetation in the river and on the banks and sand substrate that has frequent gravel and pebble

[11] Daguet, C., 2007. *Dragonflies and damselflies in your garden* (online). © Natural England. Available from: http://www.britishdragonflies.org.uk/sites/britishdragonflies.org.uk/files/images/GardenDragonflies_0.pdf (Accessed 17/09/16).

[12] British Dragonfly Society (BDS)., ca. 2016. *Beautiful Demoiselle* (online). Copyright of the British Dragonfly Society. Available from: http://www.british-dragonflies.org.uk/species/beautiful-demoiselle# (Accessed 17/09/16).

within. The area provides the ideal habitat requirements for this species. Often seen flying around the grasses on the bank side, it is important that these areas are maintained.

Banded demoiselle

This species prefers slow-flowing rivers and canals[11].They like emergent vegetation and muddy substrates [13]. Flying season is mid-May to early September[11].

Although the survey was conducted in prime flying season, this species was not seen. However, the river provides the factors this species requires, other than the river substrate. The fact they had not happened to be seen does not mean they do not use the area. However, Beautiful demoiselle males are very territorial[14] and perhaps their abundance in the area deters the Banded demoiselle.

Emperor dragonfly

This species prefers well-vegetated ponds, lakes, ditches and canals[11].Particularly those with slow flowing water and abundant submerged and floating vegetation [15].Their flying season is late May to early September[11].

Again, although prime flying season, this particular species was not seen. However, this could be due to the fact that it is slightly less specialised in terms of habitat. The river above Ebblake stream, does have slow flowing water and is abundant in vegetation types. Therefore, provides ideal habitat once again.

To summarise the findings overall, I would begin by stating that this particular river is of high ecological importance for the dragonfly and damselfly species, in particular those like the Banded demoiselle, Emperor Dragonfly and particularly the Beautiful demoiselle. When comparing species requirements to the physical attributes and vegetation structure recorded for the river above Ebblake stream, it is clear that it currently provides almost all of the preferred conditions. In particular, flow type and vegetation structure. The only issue would be that the amount of sunlight to the river is minimal, due to a high volume of trees and overhanging boughs. However, there are areas of scattered trees and patches where sunlight is heightened and therefore, if these conditions are maintained the area should continue to suit all dragonfly and damselfly species. In particular, those more specialised, like the beautiful demoiselle. The Azure damselfly is also an indicator of sheltered habitats, due to the fact these species prefer sheltered areas[11].Therefore the sightings of this species at this area supports the findings that it is a shaded and quite sheltered river.

I would suggest that vegetation, because already so complex and abundant be managed via regular cutting. It is a very important part of the habitat but if left to become too congested it could become an issue, especially the aquatic plants as they could change the rivers natural chemistry via nutrient increase. The amount of oxygen in the river would then be depleted and lower the chances for species reproduction. Also cutting back some of the larger tree branches that are causing heightened shade is worth considering. Once more sunlight is available in addition to the shaded and sheltered

[13] Nature Spot., ca. 2016. *Banded Demoiselle - Calopteryx splendens* (online). Copyright of Nature Spot. Available from: http://www.naturespot.org.uk/species/banded-demoiselle (Accessed 17/09/16).

[14] Wildlife Trusts., ca. 2016. *Banded demoiselle Calopteryx splendens* (online). Copyright of The Wildlife Trusts. Available from: http://www.wildlifetrusts.org/species/banded-demoiselle (Accessed 17/09/16).

[15] Nature Spot., ca. 2016. *Emperor Dragonfly - Anax imperator* (online). Copyright of Nature Spot. Available from: http://www.naturespot.org.uk/species/emperor-dragonfly (Accessed 17/09/16).

areas, this river area could provide all of the necessary requirements for dragonflies and damselflies to thrive.

Fig 11. Large tree with overhanging boughs and dense, complex vegetation on bank side at the river above Ebblake stream.

Fig 12. Area of river above Ebblake stream showing areas of shade and light.

Ebblake Stream

(Downstream start Easting: 410552 Northing: 106516)
Date of Survey: 10/06/16 Weather – overcast and mild
Authors: Lucia Parker and Rachel Richards.

Fig 13. Ebblake stream survey stretch starting at downstream point

Physical attributes of the river site

Along the 100m of the Ebblake stream both banks were comprised of earth the channel has a silt substrate with slow flowing, smooth water. There were no obvious bank modifications or channel features.

500m sweep up of the site

Both banks have mixed broadleaved woodland, scrub and shrub, rank vegetation and parkland and gardens within 50m of the bank top with additional grassland on the right bank. Both banks had gentle bank profiles.

Bank top land use and vegetation structure at the site

Trees were present on both banks with shading occurring over 33% of the channel. Overhanging boughs, exposed roots, large woody debris and channel leafy debris were al present. There was no

channel vegetation present. Banks had one or two pant species present on the bank face and banktop.

Spot check breakdown

Site One

The bank height at site one was very low, with the water depth fairly shallow and a weak flow of water. At this point, there was a moderate amount of vegetation on the bank top giving the stream a lot of canopy cover which was shading the stream from direct sunlight and may have lowered the local temperature.
There was no channel vegetation and only one or two species of plant on the bank faces of the stream. No dragonflies or damselflies were observed at site one.

Site Two

Again at site two, the bank height was low, with the gradient of the bank face very gentle. The flow of water was almost stationary at site two and as a result, the water appeared almost stagnant with very few signs of life and no channel vegetation. There was less canopy cover at the second site as the bank top had more scrub-like foliage with less trees.
Again, no dragonflies or damselflies were observed at this site.

Summary of Ebblake Stream

Ebblake stream is set above Ebblake itself and was noticeably shallower with a very low flow compared to the other areas surveyed around Ebblake and the River Crane. Although we could only survey two sites along Ebblake stream, it was notable that no dragonfly or damselfly species were observed at either site.

This could be down to many reasons, including time of day (Approximately 3pm) or the weather conditions. However it is more likely to be due to the reduced water depth along this length of the river which in turn has resulted in a low abundance of channel vegetation. The low gradient of the banks along Ebblake stream has also led to a very low diversity of plants growing on the banks. Many dragonfly and damselfly species, including the most frequent visitors of the River Crane like the Banded and Beautiful Damoiselle and the Emperor Dragonfly require there to be a fair amount of vegetation within their habitat for several reasons including territorial displays, breeding and feeding. Another factor which may affect the presence of dragonflies is the substrate of the river. At the two sites surveyed along Ebblake stream, the river bed was predominantly silt, which is unfavourable to

the larvae stage of some damselflies such as the Beautiful Demoiselle who prefer gravel or sandy substrates[16].

In both their adult and larval forms, the Beautiful Demoiselle requires bank and channel vegetation and so this may well explain their absence from the stream. Interestingly in the case of the Beautiful Demoiselle, the larvae are particularly sensitive to the oxygen content in the water[17] meaning that the stagnant appearance of the water and build-up of sediment in the sites we surveyed may be creating an incompatible habitat for the larvae of the damselfly.

The Banded Demoiselle, another frequently seen species along the River Crane, prefers silt channel substrate however similarly to the Beautiful Demoiselle, it too needs tall bank vegetation for territorial displays and floating channel vegetation for breeding[18].

Another important visitor to the River Crane, but missing from Ebblake stream is the Emperor Dragonfly. Although it favours slow-moving or still waters and is known to be able to withstand stagnant water bodies, we still didn't observe any during our surveying and although this may have been down to variable conditions, it is more likely to be again due to the lack of floating channel vegetation which is required by the Emperor Dragonfly for reproduction [19].

[16] http://www.british-dragonflies.org.uk/species/beautiful-demoiselle

[17] http://dictionary.sensagent.com/beautiful%20demoiselle/en-en/

[18] http://www.british-dragonflies.org.uk/species/beautiful-demoiselle

[19] http://online-field-guide.com/Anaximperator.htm

River Crane/Moors After Ebblake

(Downstream start Easting: 410307 Northing: 106107)
Date of Survey: 06/06/16 and 10/6/16
Author: Lucia Parker and Rachel Richards.

Fig 14. After Ebblake survey stretch starting at downstream point

Physical attributes of the river site

The bank material was earth along the whole 500m stretch. Most of the stretch appeared to have no bank modifications with the only obvious reinforcement in section one and four from the downstream start point. The predominant channel substrate is sand when it was visable and the water flow was mostly smooth with a few rippled areas.

500m sweep up of the site

Both banks have mixed broadleaved woodland, scrub and shrub, grassland and parkland and gardens within 50m of the bank top. Both banks had greater than 45˚ bank profiles.

Bank top land use and vegetation structure at the site

Trees were present on both banks with shading occurring over 33% of the channel. Overhanging boughs and large woody debris were present on the bank tops. Within the channel leafy debris and debris dams were present. Amphibious and submerged broad leaved channel vegetation was present along the stretch. Banks were either bare or had one or two plant species present on the bank face and bank top.

Spot check breakdown

Site One

Five Beautiful Demoiselles spotted.
Structurally, both the left and right bank consisted of a steep gradient made up of an earthy substrate. The banks stood at approximately 0.64m. The left bank had a bank modification in the form of a (plastic) reinforced entry point.
Dense vegetation consisting of over four or more plant species lined the right bank top, with a simpler coverage of two or three vegetation types lining the left bank top. This decrease in plant biodiversity on the left bank may be due to the human use of land bordering this bank.
The amount of aquatic vegetation was reasonably high at this particular site, with a selection of both amphibious species as well as submerged linear leaved species, crucial for certain dragonfly and damselfly early larval life stages.

Site Two

3 damselflies spotted (suspected to be Beautiful/Banded).
Site two had a very similar bank structure to site one. Again both banks consisted of earth and met the river at an abrupt angle. However, the left bank top was measured to be 0.95m and was the highest bank measurement recorded throughout the entire survey. This very much contrasted with the right bank top height as was observed at 0.64m.
The vegetation lining the banks was noticeably limited in regards to number of species. With one predominant species observed on the right bank, along with only two or three species observed on the left bank.
In terms of amphibious and aquatic vegetation; this site was relatively diverse. There appeared to be amphibious species as well as both submerged broad leaves and submerged linear leaved.

Site Three

Many pied wagtails inhabited the area.
2 damselflies spotted (suspected Banded/Beautiful)
Both river banks at this site consisted of an earthy

substrate and where measured to be an equal 0.7m.
The river was observed to be slightly narrower than the two previous sites which explained why the water level was slightly higher here also.
The vegetation was noticeably dense consisting of only two or three plant species on both sides of the bank.
Emergent broad leaved herbs where situated within the stream, along with various species of amphibious and submerged broad leaved vegetation.

Site Four

Species of damselflies and dragonflies present.
Each bank met the river at a steep gradient and it was established that both banks consisted of an earthy substrate. Artificial piping was present at this specific sight, situated on the left bank.
The vegetation was fairly sparse on the both banks, with the left bank face observed to be completely bare in comparison to the previous sites.
Although the bank vegetation seemed to be relatively sparse, the aquatic vegetation was fairly substantial; with species of emergent herbs, submerged broad and linear leaved present.

Site Five

Dragonflies and damselflies absent.
Both banks consisted of an earthy substrate and met the river in a more gradual decline in comparison to the other sites.
The vegetation lining the left bank was recorded to consist of predominantly one species, with two or three species spotted on the opposing bank.
The aquatic vegetation was fairly dense. Emergent broad leaved herbs, aquatic and submerged broad leaved species where spotted.

Site Six

Damselflies and dragonflies absent from area.
Both banks where measured to be relatively level at 0.74m and made from earth. No bank modifications had taken place at this location.
A diseased alder tree was observed overhanging the river on the right bank, casting shade over a large proportion of the river.
The species diversity in terms of vegetation was relatively limited at this specific site. Each bank consisted of only two or three vegetation types.
Emergent broad leaved herbs, floating leaves (rooted), amphibious and submerged linear leaved species where observed within the river itself.

Site seven

Lots of dragonflies and damselflies (suspected Beautiful/Banded)
Again, the banks where made of earth and met the river at a very gradual decline, resulting in easy access to the river.
There was a lack of diversity in terms of bank vegetation with only one dominant species appearing consistent on both banks at this specific site.
Emergent broad leaved herbs, aquatic and submerged broadleaved species where recorded to be situated within the river.

Site eight

Very little dragonfly and damselfly activity.
Relatively easy access to the bank due to gradual decline. Both left and right bank consisted of an earthy substrate.
The vegetation was recorded to be fairly limited in diversity, with one dominant species consistent on the left and right bank.
In terms of aquatic vegetation, this site proved to be the most diverse when compared to the previous sites; with species of: emergent broad leaved herbs, floating leaves (rooted), amphibious, submerged broad and linear leaved species present.

Site nine-

No damselfly or dragonfly activity.
Both banks were noticeably steep and made of earth.
Alder trees where observed on the left bank, providing dense coverage to this portion of the river. The remaining vegetation consisted of one predominant species, along with areas of bare ground.
Emergent broad leaved herbs, rooted floating leaves, amphibious and submerged broad leaved species where present within the river.

Site Ten

No damselfly or dragonfly activity.
The formation of both banks closely resembled that of the previous site; relatively steep and consisting of an earthy substrate.
In terms of bank vegetation, this site was very similar to the previous site too. With one predominant species observed along with areas of bare ground.
This was the only site on the entire survey in which aquatic plant species where completely absent.

Summary of After Ebblake

After Ebblake was a stretch of the River Crane which ran above Ebblake itself and we surveyed 10 sites along a 500m stretch of its length. At the majority of the sites surveyed, dragonfly and damselfly activity was observed - with the Banded and Beautiful Demoiselle damselfly species making up most of the numbers we recorded.

Dragonfly and damselfly activity appeared to decrease in the last few sites and although this may have down to changes within the habitat such as the diversity of bank face vegetation decreasing, it could also be due to the fact that the last 3 sites were surveyed on a separate day and therefore the environmental conditions would have varied such as time of day and weather conditions.

As for the rest of the survey sites, the requirements most needed by the majority of dragonfly and damselfly species were met – at most sites, there were multiple species of channel vegetation which broke the surface of the water as well as sturdy bank structures with a diversity of plant species. The flow of the river was not extreme enough to discourage species which cannot survive in rivers with a too-fast or too-slow stream of water and so it is possible that a great number of dragonfly and damselfly species could habituate the After Ebblake portion of the River Crane.

The Beautiful Demoiselle was the most frequently seen species along After Ebblake which is not surprising considering that it is found to favour sandy substrates[20] and where possible to see, the majority of the sites surveyed had a sand channel bed. This stretch of the river had a high abundance and diversity of mid channel vegetation which again supports the presence of the Beautiful Demoiselle as it requires channel plant life for not only the larval stages of its life but also for the act of laying eggs [21].

The Banded Demoiselle was also frequently seen along After Ebblake which again is unsurprising as one of the species main requirements is bank and mid-stream vegetation[22].

The Emperor Dragonfly is another species which needs a lot of protruding plants for many aspects of its life[23] but despite this being in ample supply, we did not observe any of these beautiful dragonflies along the stretch of the River Crane that we surveyed. This may be because the Emperor Dragonfly favours very slow moving or still water bodies[24] and so would have been present in other areas such as Ebblake but unable to survive along parts of the River Crane such as After Ebblake.

[20] http://www.denbighshirecountryside.org.uk/beautiful-demoiselle/

[21] http://shropshiredragonflies.co.uk/beautiful-demoiselle/

[22] http://www.arkive.org/banded-demoiselle/calopteryx-splendens/

[23] http://www.arkive.org/emperor-dragonfly/anax-imperator

[24] http://www.naturespot.org.uk/species/emperor-dragonfly

Lower Crane/Moors River

(Downstream start Easting: 410508 Northing: 105622)
Date of Survey: 06/06/16
Authors: Clemency Carroll and Luke Anning

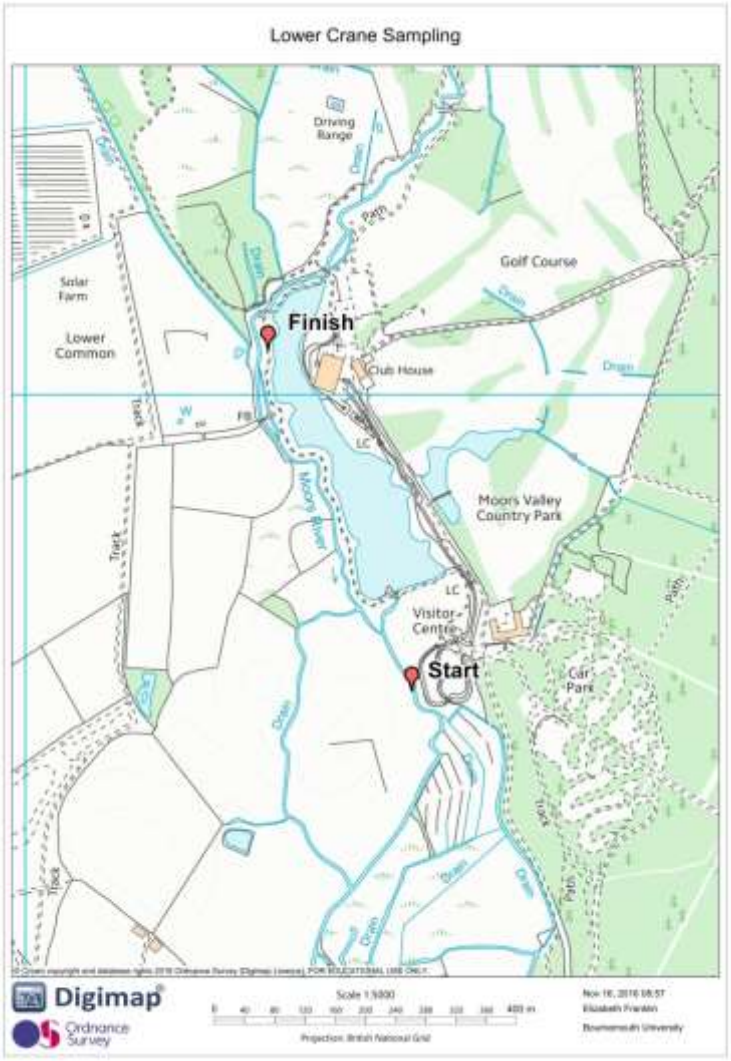

Fig 15. Lower Crane/Moors survey stretch starting at downstream point

Physical attributes of the river site

This section of the river was surveyed from the left bank faces. The valley from was a concave/bowl with a distinct valley bottom. 8 riffles and 4 vegetated point bars were views. 1 culvert and 1 bridge were present on or above the river and 33% or less of the river was impeded by a weir or dam. The left and right bank's materials, for the first nine survey points, were classified as earth apart from the last survey point, where a concrete embankment had been placed. The left bank modifications were not seen or not known for points 1-4 and 7-9. Points 5 and 6 on the left bank saw an embankment whilst point 10 saw the left bank having a resectioned bank modification. The right bank showed a lot of variety in the data. At survey points 1 and 3 the right bank had a poached bank, whilst survey points 2 and 8 showed no seen or unknown bank modifications. Points 4-7 and 9 suggested an

embankment and point 10 saw the right bank having a resectioned bank modification. Marginal and bank features for the left side were not visible for all the survey points apart from survey point 10 which had a stable cliff feature. For the right side bank there was a vegetated side bar for points 1, 4, 5 and 6. For survey points 2, 3, 7, 8 and 9 there was no marginal or bank features and for survey point 10 there was yet again a stable cliff feature.

The channel substrate was listed as earth for all of the ten survey points. The flow type displayed was smooth downstream and further upstream at survey points 3-7 the flow was rippled. Survey points 8 and 10 were again smooth whereas, on survey point 9 the flow type was unbroken standing waves.

The channel modifications for survey points 1, 2 and points 4-8 were not known or there were none. For survey points 3 and 9 there were dams and at survey point 10 the flow the channel modifications were culverted. The channel had a few different features. At survey points 1,3 and 4 the channel features viewed were vegetated mid-channel bars. There were no features at survey point 2, as well as survey points 5-8. At the penultimate survey point 9 the features dictated were trash and finally survey point 10 had exposed bedrock on display.

In summary the river's physical attributes are as follows:

- Left and right bank material predominantly earth with a concrete material at the most upstream point
- Left bank had no obvious bank modifications or features other than occasional embankments, one resection and a stable cliff feature
- Right bank had a variety of different modifications including poached banks, embankments, vegetated side bars and a stable cliff feature
- The channel substrate is earth with a variety of features including vegetated mid-channel bars, trash and exposed bedrock
- The channel modifications featured an occasional dam and a culverted section
- The flow type is rippled with occasional ripples and an unbroken standing waves section

500m sweep up of site

Land use within 50m of the left river banks was a mixture of broadleaved mixed woodland; coniferous woodland; scrubs and shrubs; wetland; artificial open water and parkland and gardens. On the opposing right side river bank the land use within 50m was scrubs and shrubs; natural open water and rough/ unimproved grassland.

The left bank implied a bank profile that was varied; ranging from a vertical with toe and steep >45-degree angle to a gentle bank profile. The right bank gave a gentle to composite bank profile.

The trees on both banks were regularly spaced or single.

There were overhanging boughs and shading of the channel present, as well as, fallen trees and large woody debris. 33% or equal of the associated features of the river was exposed bankside roots or underwater tree roots.

33% or equal of the flow was free fall flow; rippled; upwelling or smooth flow. There was also 33% or equal stable cliffs and eroding cliffs. There were unvegetated and vegetated mid-channel bars present. Moreover, there was 33% or equal mature islands; vegetated side bars; unvegetated side bars; vegetated point bars and unvegetated point bars present.

Features of special interest on the river included 33% or equal debris dams; leafy debris; fens and wet woodland.

33% or more of the channel is choked with vegetation.

Bank top land use and vegetation structure at the site

The vegetation types on the left and right banks were simple and complex.

The land use within 5m of the left bank was a mixture of scrubs and shrubs and semi-natural broadleaf/mixed woodland. The opposing right side bank had predominantly improved/semi-improved grassland with a small section of rough unimproved grassland/pasture, semi-natural broadleaf/mixed woodland and scrubs and shrubs.

The left bankface started as complex, showing four or more vegetation types up to point 4 where the vegetation type became simple, with only two or three different types. The right bankface structure has a variety of uniform, simple and complex vegetation types. At survey point 1, 6 and 9 the vegetation is uniform. At survey points 3,7 and 10 the vegetation is simple and the rest (2,4,5 and 8) are complex.

The channel vegetation type is largely diverse at particular points or certain features were not visible. All vegetation types apart from submerged broad leaved were seen throughout the 500m area. These types included liverworts/ mosses/ lichens; emergent vegetation (reeds, grasses, herbs etc.); floating rooted leaves; free floating; amphibious and submerged (linear and fine leaved) and filamentous algae. All points along the survey had the majority of these vegetation types within them. The two most commonly seen at each site were emergent broad leaved herbs and emergent reeds/ sedges/ rushes/ grasses.

In summary the vegetation structure is as follows:

- Land use within 5m of the left bank is a mixture of scrubs and shrubs and semi-natural broadleaf/mixed woodland
- Land use within 5m of the right bank is predominantly improved/semi-improved grassland with a small section of rough unimproved grassland/pasture, semi-natural broadleaf/mixed woodland and scrubs and shrubs.
- Simple vegetation type dominates the left side bankface and the complex vegetation type is the most common vegetation type at all of the survey points on the right side
- Vegetation types were diverse throughout the survey and the most common were emergent broad leaved herbs and emergent reeds/ sedges/ rushes/ grasses.

Channel Dimensions

Due to lack of access or unstable unsafe ground many points of the bank could not be analysed for measurements in particular the right side of the river bank.

The left bank's bank top height for the survey points measured (1, 2, 3, 5, 7 and 8) ranged from 0.55 to 1.2m. Points 1 and 7 had the same bank top and embanked height of 1.2m and 0.55m. Points 2, 3, 5 and 8 had a separate bank top height to their embanked height. The embanked height ranged from 0.25m to 1.2m.

The right bank could only be accessed at survey point 8. The bank top height was the same as the embanked height at 1.3m.

The channel dimensions could only be accessed at survey points 3, 5 and 8. The bankfull width ranged from 2.8m to 5m. The water width ranged from the 2.8m to 5m as well. The water depth equalled from 0.35 to 0.68m.

Requirements for Dragonflies and Damselflies

Dragonflies and damselflies fall into the taxonomic Order of Odonata, translating to 'toothed jaws'.

Although they are inclusively referred to as dragonflies, dragonflies and damselflies are in fact two discrete groups. The major differences between the two group are identified as in the table below:

Dragonflies	Damselflies
Stronger fliers	Weaker fliers
Larger than damselflies; sturdier body	More slight than dragonflies
Hold wings open at rest	Hold wings closed at rest
Hindwings are generally shorter and wider than the forewings	All four wings are of the same size and shape
Large eyes, positioned close to one another, and often touch	Smaller eyes which never touch, on either side of their head

Both dragonflies and damselflies are creatures of the sun, and are often seen on warm days between April and October. Despite having said this, the morphological differences between the two groups indicates that their habitat requirements may vary between one another. When considering attracting dragonflies to a location in the future, some key factors must be taken into consideration:

- Clean unpolluted water with shallow margins
- Location must be in direct sunlight where possible
- Sheltered far from strong winds
- Aquatic vegetation should include a combination of submerged plants and floating leaved plants. These can include pondweeds, crowfoots, waterlilies and frog-bits.
- Water pollution should be avoided at all costs
- Too much shading will inhibit the growth of vegetation
- No fish – fish are the primary predators of dragonflies and damselflies
- Waterbirds – also predate on dragonflies and damselflies and damage vegetation

Based on the aforementioned factors, we can observe a number of ways to ensure the abundance of the dragonfly and damselfly population within Moors Valley Country Park. On top of considering requirements for dragonflies and damselflies, they could also be conserved further by thinking about the current threats. Threats include habitat loss (mainly from development), absence of suitable management strategies and overstocking water deposits with fish and water dwelling birds[25].

Having identified the previous habitat preferences, overall it can be said that a crucial element in the conservation of dragonflies and damselflies is the water quality in relation to it as a potential habitat for larvae; due to the fact that the majority of larvae species are sensitive to pollution. This can be used as a gauge to monitor how healthy the site in which these larvae are present in. The prime habitat would consist of a combination of both long and short grass, with some scrub and woodland nearby. If all these factors are taken into account, it would provide an ideal ground for normal, healthy behaviours such as hunting, roosting and basking[26].

Despite having discussed the general needs of dragonflies and damselflies it should be recognised that certain species require more specific requirements:

[25] Daguet, 2007. Natural England [online] Available from http://www.british-dragonflies.org.uk/sites/british-dragonflies.org.uk/files/images/GardenDragonflies_0.pdf [Accessed 14th September 2016]

[26] Scottish Natural Heritage, n.d. SNH [online] Available from http://www.snh.org.uk/publications/on-line/naturallyscottish/dragonfly/Conservation.asp [Accessed 29th September 2016]

1. Banded Demoiselle: Prefer canals and slow moving rivers, still ponds, and amongst lush vegetation[27]

   The data indicates few Banded Demoiselles habituating in this area of the river, however, the data also demonstrates that around 70% of vegetation was marked as 'Not Visible'. This could be a reason for the lack of species due to what was said previously about preferences for vegetation. Hence, there is a correlation between amount of vegetation and abundance of Banded Demoiselles.

2. Beautiful Demoiselle: These are Generally found along rivers and streams, especially those which beds are composed of gravel or sand [24].

   Data demonstrates that the abundance of the Beautiful Demoiselle fluctuates with the weather; on sunnier days there was an increase in Beautiful Demoiselles noted at the location. This information would fit in accordance of general dragonfly preferences.

3. Emperor Dragonfly: These are mostly found populated in areas with large, heavily vegetated areas of water, such as pond and lakes, however have sometimes been spotted near slow moving rivers and canals [24].

   Few Emperor Dragonflies were spotted at this location, possibly due to the fact that this species is only sometimes found in slow moving rivers, and actually prefers ponds and lakes, as opposed to rivers. Despite the fact that the river was noted as being slow moving, there was still little abundance of this species in this location, which is where this area could perhaps be improved.

Summary and Improvements for Dragonflies and Damselflies

To summarise the vegetation even though it is diverse and complex may need to be managed better by regular cutting back and weeding. If the habitat becomes too congested because of competition from weeds and dominant plants it could become an issue especially as aquatic plants can change the river's natural chemistry and nutrient content. If the oxygen content of the river decreases, then this lowers the chances for species reproduction for aquatic species and dragonfly and damselfly larvae. Based on the data collected and the aforementioned factors regarding the abundance of dragonflies and damselflies, a number of improvements and recommendations could be taken into consideration in order to increase the population size of these species within Moors Valley Country Park.

From both my observations of this site, and the data provided, I would suggest that the most apparent factor affecting the number of dragonflies and damselflies in this location is the amount of overhanging vegetation. Out of the 10 intervals that we analysed at the Lower site, almost all of the locations were heavily shaded and lacking appropriate amounts of sunlight. I would be under the impression that this excessive vegetation is not necessarily intentional, and is in fact as a result of limited management. I would therefore suggest that this congestion of vegetation is more closely monitored, and cut more regularly until it stops creating as much shade. I understand that whilst the vegetation needs to be cut, it is also crucial to other aspects of the parks' biodiversity; a balance should be struck between maintaining this biodiversity and creating an increased amount of sunlight for the dragonflies and damselflies.

[27] British Dragonfly Society, 2016. BDS [online] Available from http://www.british-dragonflies.org.uk/species/emperor-dragonfly [Accessed 14th September 2016]

Overview of Site assessment and historical data

The historical chemical data for the sites above and below the Moors Valley Park stretch have shown a decrease in ammonia found in water samples. This suggests that Moors Valley Park has not been contributing extensively to added nutrients in the watercourse. There has also not been a decrease in the dissolved oxygen measurements over time, this means that the level of oxygen should support a diversity of invertebrates and fishes. Above Moors Valley Park at Squirrel corner has an A rating by the environment agency in 2009 meaning the river is good for abstraction, very good for salmonid fisheries, good for cyprinid fisheries and natural ecosystems. Below Moors Valley Park at Conf With Crane-Palmersford has a B rating in 2009 which means the river is good for abstraction, good for salmonid fisheries, good for cyprinid fisheries and ecosystems are close to natural.

Analysis of the invertebrates for biological pollution status and sedimentation suggest an improvement in pollution score and a reduction in siltation in Moors 1 and Moors 4 sites, downstream of Moors Valley Park. Below Moors Valley Park at Conf With Crane-Palmersford has a B rating in 2009 which the river's biology is a little short of an unpolluted river. In addition information from the environment agency suggests that above Moors Valley Park at Squirrel corner has an A rating for biology meaning the river's biology is similar to that expected for an unpolluted river. Despite this, there is also evidence that increased siltation is changing invertebrate communities upstream of Moors Valley Park. However, biological indicators suggest that for both pollution and siltation Moors Valley Park has not historically had a detrimental effect on freshwater invertebrate communities.

The river habitat surveys indicate that on the whole the river has a good level of emergent and amphibious vegetation and a sandy, pebbled river bed in the above Ebblake, After Ebblake and Lower Crane areas. Of these areas, there is a good mix of shaded and open canopy areas in the Upper and After Ebblake sections of the river but the Lower Crane section appears to have heavy shading along the majority of the length. In the Ebblake stream however, silt is the predominant river substrate and there is no emergent or amphibious vegetation. The Ebblake stream is also heavily shaded at the lower end.

Conclusions for management in respect to damselflies and dragonflies

The natural or near natural biological and chemical state of the Crane/Moors river up to 2009 and the overall improvements in biological pollution scores suggests that this habitat is good for dragonfly and damselfly larvae. The presence of emergent or amphibious vegetation over most of the stretch of the Crane/Moors through Moors Valley Park is also excellent for dragonfly and damselfly lifecycles; for emerging nymphs and resting adults. During this survey Azure Damselflies, Large red Damselflies, Beautiful Demoiselles, Banded Demoiselles and Emperor Dragonflies were identified around the region of the Crane/ Moors River.

From the surveys shading and siltation were identified as possibly reducing habitat suitability for dragonflies and damselflies:

- Areas with high shading from the tree canopy and scrub appeared to be less desirable to the dragonflies and damselflies. The two surveyed areas with the greatest shading were the lower Crane and the Ebblake stream.
- The flow in the Ebblake stream was low, the river bed silted and no river vegetation this produces an undesirable habitat for riverine species of dragonfly.

Topics for further investigation

It would be of interest to explore the effects of previous lake dredging activity on the historical biological and chemical data from the Environment Agency. This would give reliable information on the impact of lake dredging and the resilience of the freshwater invertebrate community.

It would also be beneficial to conduct up to date chemical and biological pollution assessment at the park to ensure that historical trends of improvement have continued and to troubleshoot if not.

Appendix

Appendix I River Habitat survey form

Appendix ii Historical biological pollution data

Site	Date	ASPT	Psi	Season	Year	Site Name
SU-09300-07600	07-May-91	5.363636	45.58824	spring	1991	Crane
SU-09300-07600	29-Jul-91	5.461538	44.57831	summer	1991	Crane
SU-09300-07600	06-Nov-91	5.272727	51.85185	autumn	1991	Crane
SU-09300-07600	14-May-92	5.75	55.81395	spring	1992	Crane
SU-09500-07600	05-Nov-92	5.36	52.17391	autumn	1992	Crane
SU-09500-07600	08-May-95	5.727273	42.85714	spring	1995	Crane
SU-09500-07600	09-Oct-95	5.592593	46	autumn	1995	Crane
SU-09500-07600	20-Mar-97	5.44	37.5	spring	1997	Crane
SU-09500-07600	23-Sep-97	5.444444	42.42424	autumn	1997	Crane
SU-09500-07600	30-May-00	5.666667	43.18182	spring	2000	Crane
SU-09500-07600	20-Nov-00	5.884615	48.78049	autumn	2000	Crane
SU-09500-07600	13-May-02	6	37.03704	spring	2002	Crane
SU-09500-07600	29-Oct-02	5.72	45.71429	autumn	2002	Crane
SU-09500-07600	13-Apr-05	5.818182	41.17647	spring	2005	Crane
SU-09300-07600	29-Sep-05	5.9375	18.18182	autumn	2005	Crane
SU-09300-07600	19-Apr-90	5.190476	37.93103	spring	1990	Crane
SU-09300-07600	23-Jul-90	4.904762	41.93548	summer	1990	Crane
SU-10400-06200	22-Oct-90	5.5	52.5	autumn	1990	Crane
SU-10400-06200	24-Apr-97	5.411765	33.92857	spring	1997	Moors 1
SU-10100-04700	13-Nov-97	5.103448	39.62264	autumn	1997	Moors 1
SU-10100-04700	24-Apr-91	5.608696	44.44444	spring	1991	Moors 1
SU-10100-04700	25-Jul-91	5.37931	45	summer	1991	Moors 1
SU-10100-04700	21-Oct-91	5.111111	61.29032	autumn	1992	Moors 1
SU-10100-04700	06-May-92	5.944444	65.38462	spring	1992	Moors 1
SU-10100-04700	14-Sep-92	5.409091	42.85714	autumn	1992	Moors 1
SU-10100-04700	27-Apr-93	5.4	43.33333	spring	1993	Moors 1
SU-10100-04700	19-Jul-93	5.5	57.89474	summer	1993	Moors 1
SU-10100-04700	27-Oct-93	5.368421	40	autumn	1993	Moors 1
SU-10100-04700	29-May-95	5.761905	61.11111	spring	1995	Moors 1
SU-10100-04700	09-Oct-95	6.206897	50	autumn	1995	Moors 1
SU-10100-04700	31-May-96	5.52381	56.25	spring	1996	Moors 1
SU-10100-04700	21-Oct-96	5.870968	53.7037	autumn	1996	Moors 1
SU-10100-04700	22-Apr-97	6	54.54545	spring	1997	Moors 1
SU-10100-04700	13-Nov-97	5.65625	51.85185	autumn	1997	Moors 1
SU-10100-04700	13-May-98	5.6	47.16981	spring	1998	Moors 1
SU-10100-04700	18-Nov-98	5.655172	49.0566	autumn	1998	Moors 1
SU-10100-04700	30-May-00	6.034483	49.09091	spring	2000	Moors 1
SU-10100-04700	20-Nov-00	5.793103	54.54545	autumn	2000	Moors 1
SU-10100-04700	26-Mar-03	5.724138	55.55556	spring	2003	Moors 1
SU-10100-04700	08-Oct-03	6.428571	47.82609	autumn	2003	Moors 1

SU-10100-04700	30-Apr-04	5.916667	61.11111	spring	2004	Moors 1
SU-10100-04700	01-Nov-04	5.958333	43.58974	autumn	2004	Moors 1
SU-10100-04700	04-Apr-05	6.214286	57.14286	spring	2005	Moors 1
SU-10100-04700	29-Sep-05	6.333333	60	autumn	2005	Moors 1
SU-10100-04700	14-Mar-06	5.913043	56.75676	spring	2006	Moors 1
SU-10100-04700	20-Sep-06	6.458333	50	autumn	2006	Moors 1
SU-10100-04700	29-Mar-07	5.833333	55	spring	2007	Moors 1
SU-10100-04700	24-Sep-07	6.6	61.53846	autumn	2007	Moors 1
SU-10100-04700	10-Apr-08	6	64.51613	spring	2008	Moors 1
SU-10100-04700	22-Sep-08	6.181818	54.28571	autumn	2008	Moors 1
SU-10100-04700	27-Apr-10	6.368421	55.55556	spring	2010	Moors 1
SU-10100-04700	14-Sep-10	6.210526	60	autumn	2010	Moors 1
SU-10100-04700	21-Apr-11	6.5	60.60606	spring	2011	Moors 1
SU-09800-03800	18-Nov-98	4.263158	20.58824	autumn	1998	moors4
SU-09800-03800	24-May-93	3.823529	25.92593	spring	1993	moors4
SU-09800-03800	28-Jul-93	3.823529	29.41176	summer	1993	moors4
SU-09800-03800	24-Nov-93	3.625	22.58065	autumn	1993	moors4
SU-09800-03800	12-Jun-96	3.8125	26.92308	summer	1996	moors4
SU-09800-03800	22-Oct-96	3.705882	16	autumn	1996	moors4
SU-09800-03800	22-Apr-97	3.823529	25	spring	1997	moors4
SU-09800-03800	06-Oct-97	3.6875	25.80645	autumn	1997	moors4
SU-09800-03800	11-May-98	4.157895	28.125	spring	1998	moors4
SU-09800-03800	18-Nov-98	4.368421	31.42857	autumn	1998	moors4
SU-09800-03800	26-Mar-03	4.304348	35.48387	spring	2003	moors4
SU-09800-03800	08-Oct-03	4.583333	39.39394	autumn	2003	moors4
SU-09800-03800	30-Apr-04	4.8	36.84211	spring	2004	moors4
SU-09800-03800	01-Nov-04	5.25	34.375	autumn	2004	moors4
SU-09800-03800	03-Apr-05	5.148148	40	spring	2005	moors4
SU-09800-03800	29-Sep-05	5.296296	41.46341	autumn	2005	moors4
SU-09800-03800	14-Mar-06	4.75	53.33333	spring	2006	moors4
SU-09800-03800	20-Sep-06	5.62963	46.51163	autumn	2006	moors4
SU-09800-03800	29-Mar-07	5.25	39.47368	spring	2007	moors4
SU-09800-03800	24-Sep-07	5.740741	51.06383	autumn	2007	moors4
SU-09800-03800	10-Apr-08	5.958333	56.41026	spring	2008	moors4
SU-09800-03800	22-Sep-08	5.8	50	autumn	2008	moors4
SU-09800-03800	27-Apr-10	5.347826	51.42857	spring	2010	moors4
SU-09800-03800	14-Sep-10	5.5	50	autumn	2010	moors4
SU-09800-03800	21-Apr-11	5.5	62.5	spring	2011	moors4
SU-09800-03801	07-Nov-11	5.62963	48.88889	autumn	2011	moors4

Appendix iii Historical chemical pollution data

Year	Site	Ammonia (mgN/l)	SDEV Ammonia (mgN/l)	Dissolved oxygen (percentage saturation)	SDEV Dissolved oxygen (percentage saturation)	ASPT	Nitrates (mg/l)	Phosphates (mg/l)
2009	Crane	0.023	0.017	97.84	7.27	6.23	38.19	0.05
2008	Crane	0.022	0.014	98.37	6.7	6.23	38.53	0.06
2007	Crane	0.024	0.024	96.98	7.68	6.23	37.14	0.09
2006	Crane	0.023	0.024	98.06	7.46		37.13	0.11
2005	Crane	0.023	0.023	95.61	7.19			
2004	Crane	0.025	0.014	94.41	6.21			
2003	Crane	0.028	0.014	92.21	6.09			
2002	Crane	0.03	0.016	91.09	4.91			
2001	Crane	0.024	0.014	94.6	7.23			
2000	Crane	0.025	0.026	96.04	6.17			
1999	Crane	0.026	0.027	97.65	7.03			
1998	Crane	0.03	0.028	96.8	6.88			
1997	Crane	0.03	0.019	98.21	9.3			
1996	Crane	0.041	0.032	98.66	9.31			
1995	Crane	0.051	0.034	96.12	10.77			
1994	Crane	0.051	0.034	90.38	10.13			
1993	Crane	0.045	0.027	87.02	7.77			
1990	Crane	0.02	0.02	98.2	9.92			
2009	Moors	0.028	0.016	86.24	7.42	5.57	15.78	0.02
2008	Moors	0.032	0.021	84.26	8.1	5.57	15.42	0.02
2007	Moors	0.039	0.024	83.07	7.57	5.57	14.46	0.02
2006	Moors	0.046	0.023	84.71	6.96		14.49	0.02
2005	Moors	0.05	0.022	85.73	6.24			
2004	Moors	0.052	0.026	84.18	6.29			
2003	Moors	0.05	0.029	83.59	5.73			
2002	Moors	0.05	0.028	83.5	5.07			
2001	Moors	0.044	0.024	86.53	5.16			
2000	Moors	0.044	0.022	87.61	5.48			
1999	Moors	0.045	0.026	87.53	5.49			
1998	Moors	0.051	0.03	86.97	6.14			
1997	Moors	0.052	0.035	86.09	6.95			
1996	Moors	0.052	0.04	88.39	11.61			
1995	Moors	0.08	0.324	85.95	11.09			
1994	Moors	0.1	0.315	85.02	10.74			
1993	Moors	0.139	0.356	83.52	8.07			
1990	Moors	0.06	0.25	93.27	13.1			