Year 2 report

Citizen Crane Project

Year 2 Progress Report

Thames Water · frog environmental · Environment Agency · FORCE Friends of the River Crane Environment · ZSL LET'S WORK FOR WILDLIFE

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EXECUTIVE SUMMARY

Citizen Crane is the synthesis of several Citizen Science led water quality and ecological monitoring projects all taking place in the Crane catchment. An update on all projects is presented here with results from the 2^{nd} full year of monitoring and discussion of these results. Whilst each project can be viewed as a stand-alone piece of work with relevant conclusions (part 2.0 to part 6.0) an attempt to draw together all project elements with a view to understanding the key processes dominating the quality of water and the ecological health of the catchment has also been presented in part 9.0.

Recommendations on the use of findings to date and the future direction of Citizen Crane have been presented in part 10. The work presented here is only possible with the long-term commitment of dedicated Citizen Scientists, determined to support the restoration of the Crane catchment.

1.0 INTRODUCTION

The Citizen Crane project was set up in early 2014 to investigate the water quality in the River Crane catchment in west London using teams of citizen scientists. This report sets out the findings of the first two years of data collection and analysis, up to May 2016, and makes recommendations for future work.

The River Crane is a small urban tributary of the River Thames, with a catchment of around 125 sq km and a main channel length of around 35km, extending over five west London boroughs (Harrow, Hillingdon, Ealing, Hounslow and Richmond). The Crane Valley Partnership (CVP) was set up in 2005 and brought together representatives of these five boroughs along with the Environment Agency, Thames Water, GLA and a range of regulatory and third sector groups, to help oversee the management of the river catchment.

In October 2011 there was a major pollution incident in the River Crane, when a large volume of sewage effluent discharged into the river and wiped out much of the life in its middle and lower reaches. Thames Water acknowledged responsibility for this incident and set up the “Thames Water compensation fund” in response. This fund, administered by Green Corridor as host organisation of the CVP, sought to improve the condition of the river to better than the 2011 pre-incident base level. The Citizen Crane project was set up in line with this objective, and is supported by the Thames Water compensation fund.

The project supports a network of volunteers collecting samples and data at monthly intervals from 11 sampling sites spaced along the river system (Figure 1.1). A project team, comprising Friends of the River Crane Environment (FORCE), Zoological Society of London (ZSL) and frog environmental (FE), manages the project and undertakes the analysis of the data. A steering group, comprising Green Corridor, The Environment Agency and Thames Water, helps to co-ordinate the project and ensures it is linked into wider decision-making processes. In addition Thames Water undertakes the analysis of the water samples at their UKAS accredited laboratory

The monthly base data for each of the 11 monitoring sites comprises:

- RMI (River Monitoring Initiative) records of invertebrate life in the river
- Water samples analysed for phosphate and ammonia
- Flow data

A full explanation of how this system was set up and operates is included in the Year One report (CVP, August 2015). This year two report presents the full two year data set, provides an updated analysis of these data, develops a conceptual model of the ecosystem and sets out recommendations for future work.

The site locations are identified on Figure 1.1 (page 8). The sites are reasonably evenly spread within the upper, middle and lower sections of the river system. Site locations include monitoring sites on both of the upper branches of the river (Yeading Brook West and Yeading Brook East – also known as the River Roxbourne), regularly spaced sites along the main river corridor, and a site on the upper Duke of Northumberland's River where it enters the River Crane. The downstream site (Site 12) is on the main river at Mill Road in Crane Park, just upstream of the split between the River Crane and the lower Duke of Northumberland's River.

Data collection from all sites takes place on the third weekend of each month and this allows valid assessment of the spatial variations across the catchment. Samples are collected on the Sunday evening by a member of the project team and delivered to Thames Water at Mogden STW on Monday morning for onward transfer to the laboratories in Reading.

The second year of the project has included, in addition to the base data collection:

- An "Outfall Safari" – working with volunteers to visit and record the condition of over 230 surface water outfalls to the catchment
- Surface water outfall surveys over an extended period at selected locations
- Review of real time monitoring data collected by others
- Engagement with the public and other groups about the project

The approach to, and findings from, each of these project elements is set out in this report. The final sections of the report set out a working model of the catchment based on the overall findings to date and outline recommendations for future work. These will be reviewed with the Steering Group, and presented to the Citizen Crane teams and other interested parties, for discussion and development at the annual project forum in November 2016.

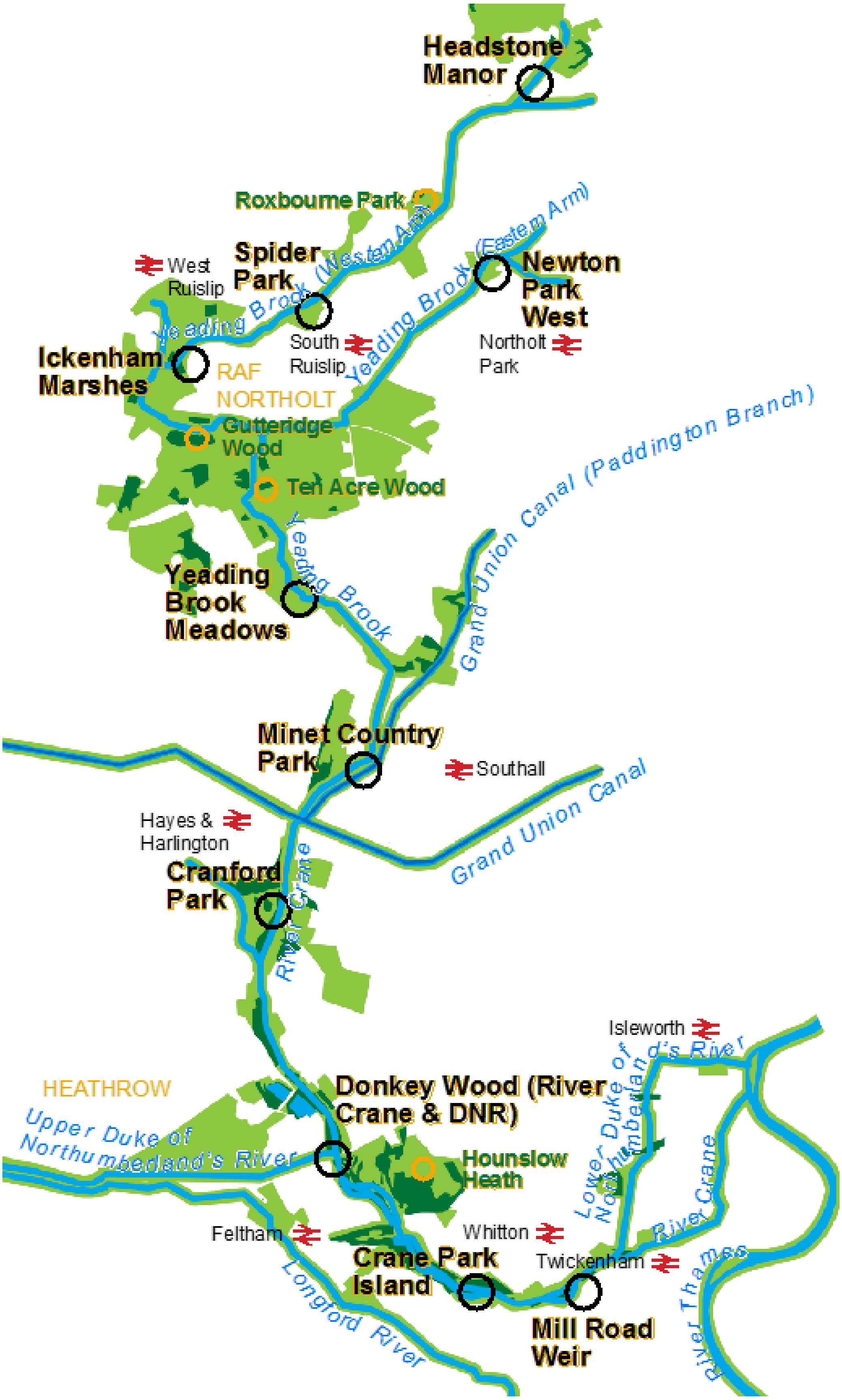

Figure 1.1 – *Map of Crane catchment showing Citizen Crane sampling points*

2.0 WATER QUALITY ANALYSIS

2.1 Methodology

A detailed methodology for the project set up and structure is provided in the year one report (CVP, 2015) and is not repeated here. Water samples are collected for laboratory analysis of phosphate and ammonia concentrations. River flow is measured using a simple installed flow gauge with a pre-determined cross-section combined with a field measure of surface velocity and water level. This is combined with the concentration data to assess the loading of phosphate and ammonia at each location in kg/day.

Two years of phosphate and ammonia concentration data have been collected at monthly intervals from up to 11 monitoring sites along the River Crane (see Figure 1.1) and the raw data are presented in Appendix A.

The samples are collected by volunteer teams and are subject to restrictions, caused for example by volunteer availability, and to safety concerns related to high water levels. There have been occasional problems with the labelling of sample bottles and sample pick up. One or two samples have also been removed from the data set due to evidently erroneous results. Given these limitations, the overall coverage of the water quality dataset is high, amounting to 93 per cent coverage over the two-year period.

Simple gauging stations set up at each monitoring location are used to estimate the flow at the time of the sampling. These gauging stations, consisting of stakes driven into one bank either 3 or 5 metres apart, are subject to vandalism and flood damage. Not all the gauges were set up and/or repaired for the full monitoring period. In addition, there have been problems with the gauging station data at some of the monitoring sites, which has led to the decision to omit data from certain sites.

Nevertheless, there has been an overall 76 per cent coverage of flow data across the sites over the two-year period. These data have enabled the calculation of regular pollutant loadings for most of the sites.

The phosphate data for each site can be compared against the threshold values for High, Good, Moderate and Poor status under the Water Framework Directive. These values vary from site to site based on the overall chemical character of the water samples. The thresholds have been calculated by the Environment Agency and are shown on Table 2.1 below.

Table 2.1 – *WFD classification according to phosphate thresholds by site* [1]

Site Number	Site Name	High	Good	Moderate	Poor
1	Headstone Manor	0.044	0.081	0.196	1.057
2	Bridgewater Fields/ Roxbourne park	0.045	0.082	0.199	1.063
4	Newton Park West	0.046	0.084	0.202	1.069
6	Yeading brook meadows	0.045	0.083	0.2	1.066
8	Cranford park	0.046	0.085	0.203	1.072
9	Donkey wood (Crane)	0.046	0.085	0.204	1.073
10	Donkey wood (DNR*)	0.05	0.09	0.213	1.093
11	Crane Park Islands	0.051	0.092	0.216	1.1
12	Kneller Gardens/ Mill Road	0.047	0.086	0.206	1.079

2.2 Water Quality Results

The data are presented in the following ways:

1. Mean annual (2014, 2015) and bi-annual (2014+2015) concentrations of ammonia and phosphorus along the length of the river
2. Mean annual (2014, 2015) and bi-annual (2014+2015) loadings of ammonia and phosphorus along the length of the river

Graphs have also been produced showing monthly concentrations and loadings of ammonia and phosphate by individual monitoring site over the 2 year data period. These graphs, along with an initial analysis of each of them, can be found in Appendix B.

The river plots show the distance from the river source at Site 1 (Headstone Manor) at km 0, downstream along Yeading Brook West and the main Crane channel, to Site 12 (Mill Road) at km 27.

Site 4 (on Yeading Brook East - also known as Roxbourne Brook), and Site 10 (on the Upper Duke of Northumberland's River), are both tributaries to this main channel, and are therefore recorded on the plot but not included in the main trend line.

[1] *Contains UKTAG information © UKTAG and database right*

2.2.1 Phosphate and Ammonia Concentrations

Figure 2.1 (below) shows the average concentrations of both phosphate and ammonia along the river over the two years of monthly data collection from May 2014 to April 2016.

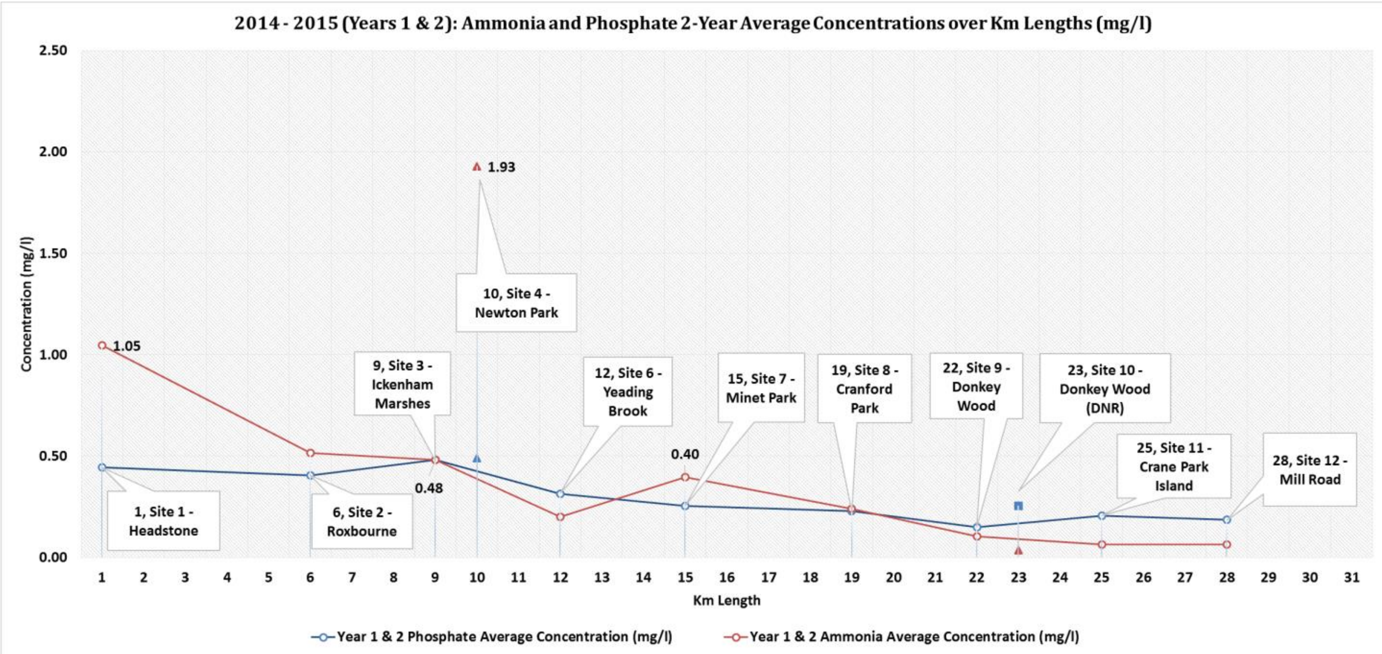

Figure 2.1 – *Average concentrations of Phosphate & Ammonia over 2 year monitoring period*

The following conclusions are drawn from this plot:

- Average concentrations of phosphate were around 0.5 mg/l in the upper reaches of both Yeading Brook West and Yeading Brook East and reduced steadily with distance downstream to around 0.2 mg/l by Mill Road in Crane Park Twickenham (Site 12). This puts the river in poor category in the upper and middle reaches, improving to moderate in the lower reaches.
- The same trend can be seen in the ammonia concentrations. Average concentrations around 1 mg/l (Headstone on the Yeading Brook West) and 2mg/l (Newton Park West) in the upper reaches trend downwards to between 0.2 and 0.4 mg/l below the confluence of these two streams and to below 0.1 mg/l below the confluence with the Upper Duke of Northumberland's River. Ammonia is targeted at below 0.6 mg/l to achieve good status for this river type.

2.2.2 Phosphate and Ammonia Loadings

Figure 2.2 shows the average loadings of phosphate and ammonia along the river over the two years of monthly data collection from May 2014 to April 2016.

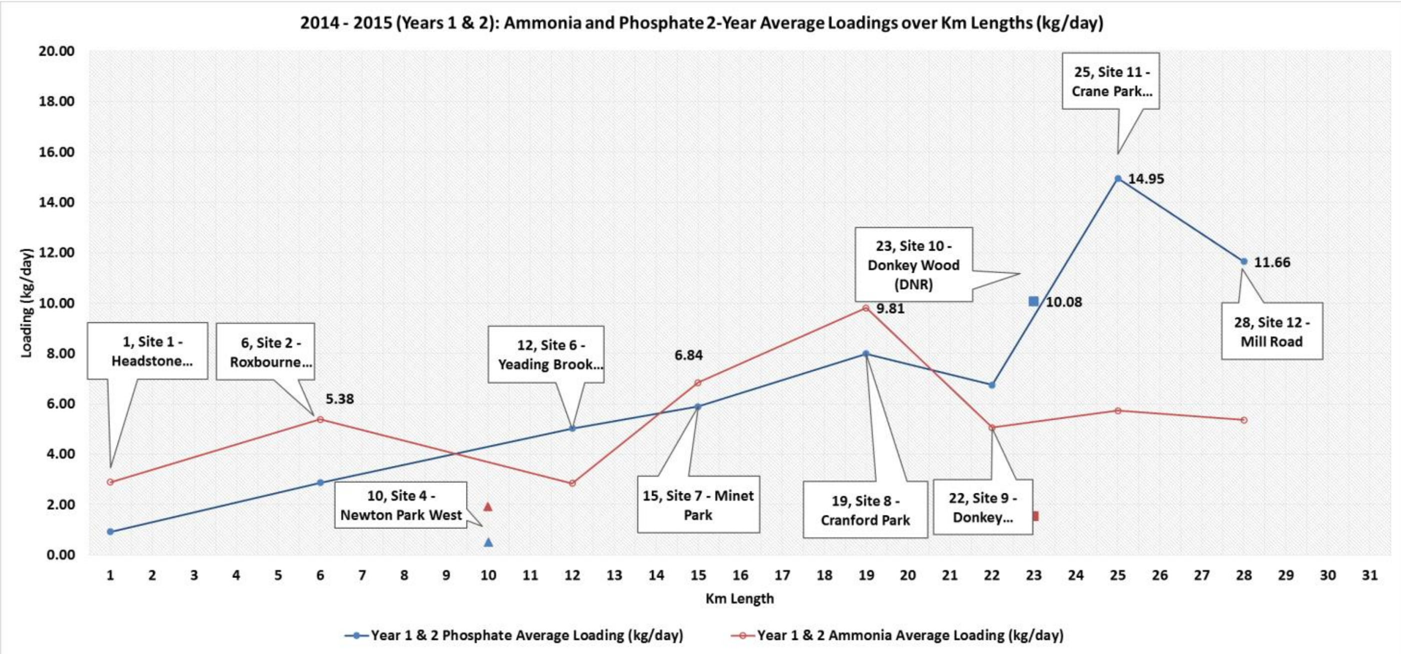

Figure 2.2 – *Average Ammonia and Phosphate Loadings along the river*

The following conclusions regarding ammonia loading are drawn from this plot:

- There is a high loading of ammonia (around 3kg/day average) at Headstone Manor at the top of Yeading Brook West. The loading reduces to around 2kg/day by Site 6 (Yeading Brook Meadows) before increasing steadily to around 10kg/day by Cranford Park. This equates to a nett input of 1kg/day/km over this 7 km reach
- Ammonia loadings fall to around 5kg/day at Donkey Wood, equivalent to a nett reduction of over 1kg/day/km over this 3km reach
- There is an input of around 1.5kg/day ammonia at the confluence with the upper Duke's River. This is followed by a slow steady decline in nett loading of around 1kg/day between this confluence and Mill Road (site 12) around 5km downstream.

The following conclusions regarding phosphate loading are drawn from this plot:

- Average loadings of phosphate increase gradually from around 1kg/day at the top of the Yeading Brook west (note that due to problems with gauging there are no loading data from Yeading Brook East) to around 8kg/day at Cranford Park (site 8). Absolute loadings start to fall between site 8 and site 9, indicating that the river ecosystem is able to remove or sequestrate phosphate (at a rate of around a kilo per day) along this 3 km reach
- There is a major input of phosphate into the system from the upper Duke's River, as measured at Site 10, equivalent to around 10kg/day, more than doubling the phosphate loading of the river at this location. This phenomenon was discussed in the year one report and the phosphate signature is considered to be due to the sewage works in the River Colne above the off-take for the upper Duke's River
- Below this input the ecosystem continues to remove or sequestrate phosphate, this time at a rate of 5kg/day over a 6km reach to Site 12 that is up to 3 times more effectively than above.

2.2.3 Annual Averages

Figure 2.3 to Figure 2.6 show the average annual concentrations and loadings of phosphate and ammonia over each year (May 2014 to April 2015 and May 2015 to April 2016), allowing a comparison between the two years.

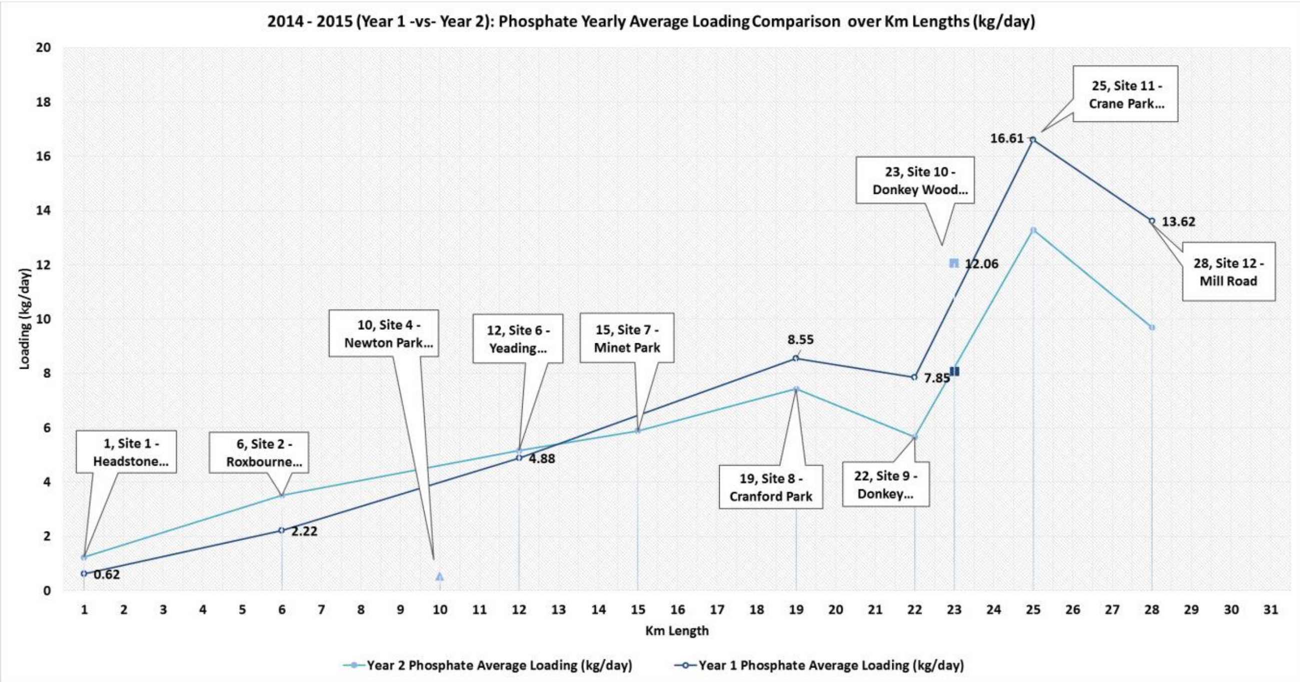

Figure 2.3 – *Phosphate yearly average loadings*

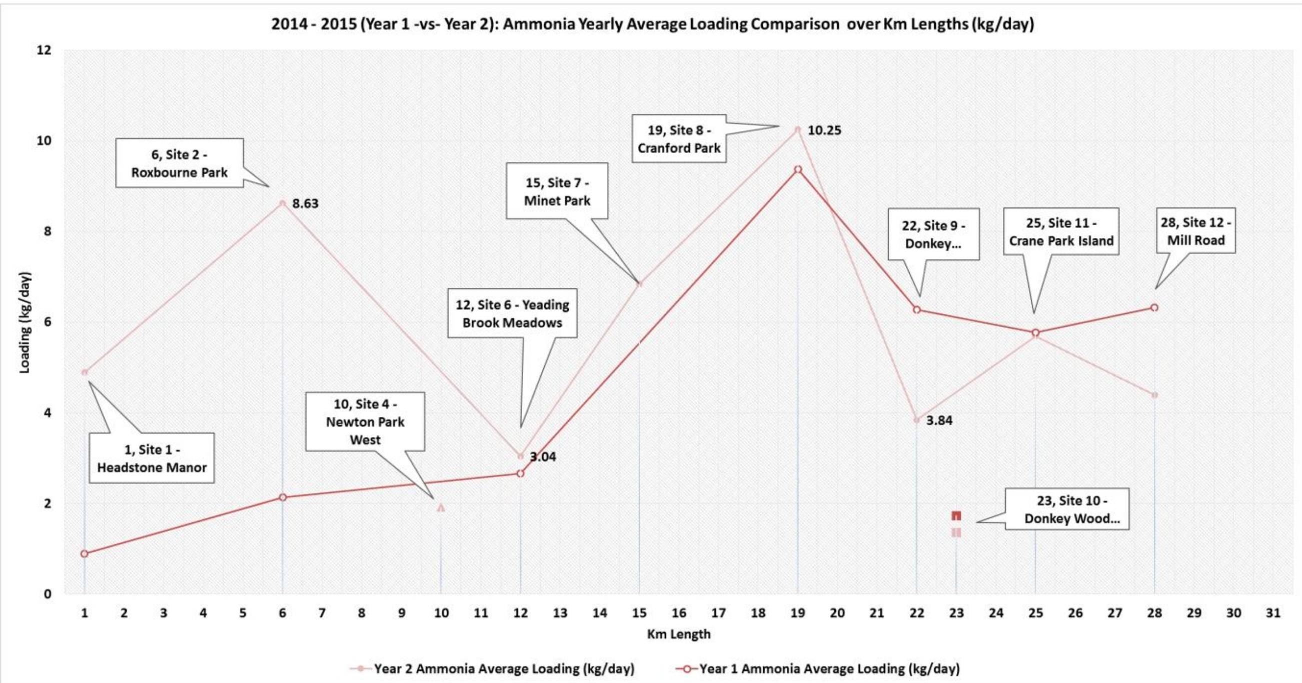

Figure 2.4 – *Ammonia yearly average loadings*

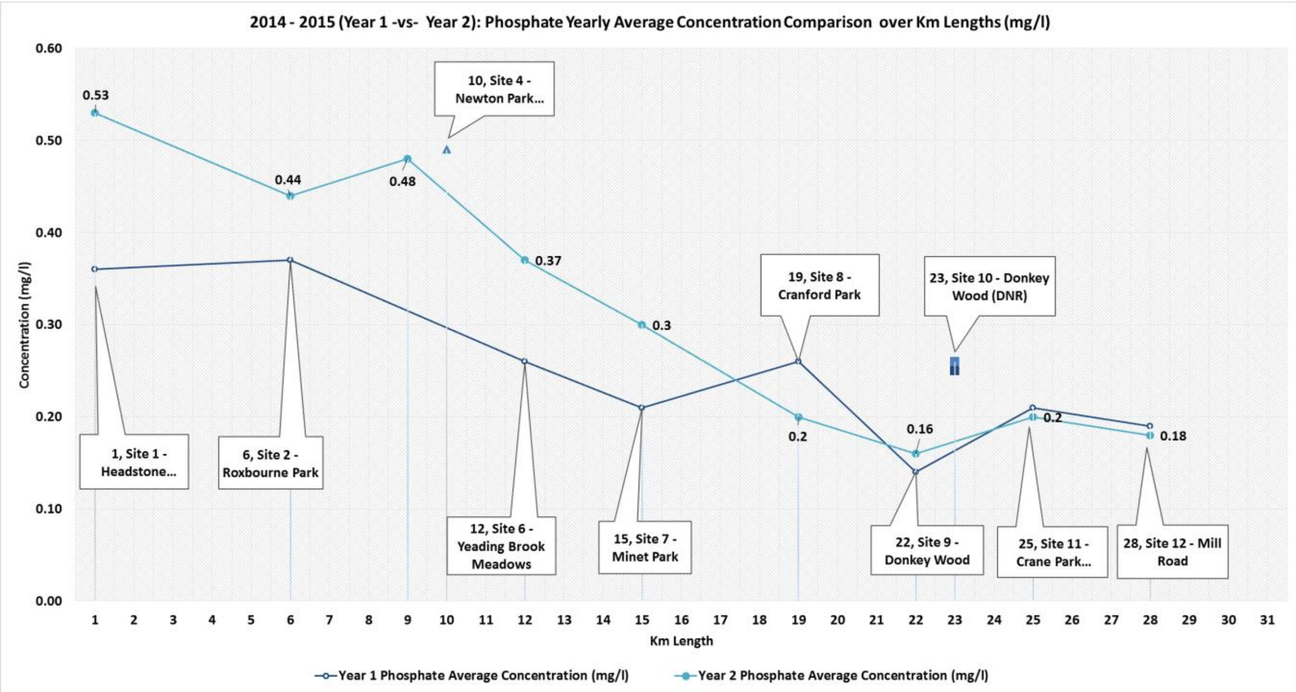

Figure 2.5 – *Phosphate yearly average concentrations*

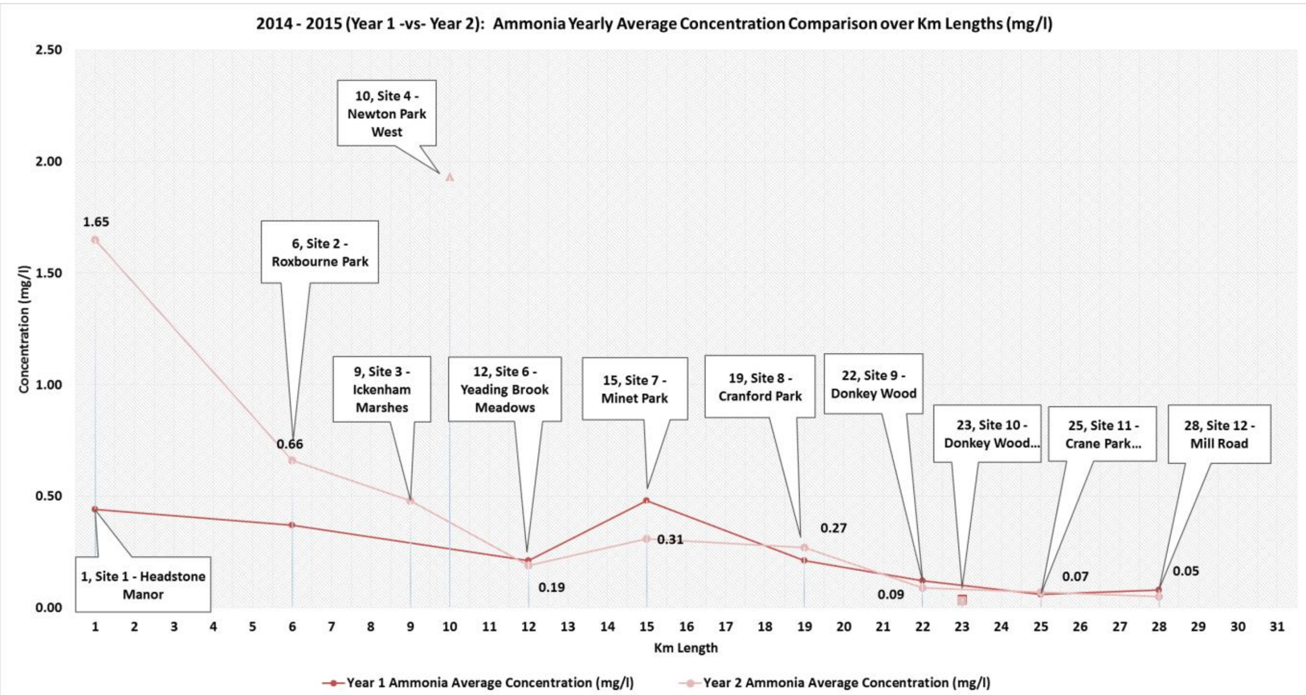

Figure 2.6 – *Ammonia yearly average concentrations*

The following conclusions are drawn from these plots:

- The plots for the two years (both concentrations and loadings) track each other closely. This indicates that; (a) the flow data are comparable over the two years; (b) the inputs are comparable and; (c) the data record is broadly reliable
- The phosphate loading data indicate an increased loading in Year Two by (a) one or more kg/day in the upper reaches of Yeading Brook West and (b) 4 kg/day from the upper Duke's River. However, this is more than counterbalanced by reductions in net loading in the middle and lower reaches of the river system. The middle reaches in the 16 km between Roxbourne Park (site 6) and Donkey Wood show a net year on year reduction in phosphate of around 4kg/day. The lower reaches in the 6km below the Upper Duke's confluence show a net reduction of 6kg/day
- The ammonia loading data show a similar pattern to the phosphate data, with higher loads upstream in Year Two and lower loads downstream. The difference in ammonia is more pronounced in the upper reach of Yeading Brook west, average loads of 1 to 2 kg/day in Year One rising to between 5 and 8kg/day in Year Two. The reduction in Year Two loads starts below Roxbourne Gardens and continues through the middle and lower reaches, such that by the lower reaches (at and below Donkey Wood) there is around 2kg/day less ammonia in Year Two compared to Year One.

2.3 Conclusions from Water Quality Results

These data consider the phosphate and ammonia concentrations and loadings across the Crane catchment over two years. The first conclusion is that the data appear to present a complex but broadly consistent picture of the levels of both phosphate and ammonia in the river.

The highest concentrations of both ammonia and phosphate are in the upper reaches of the two tributaries of the river, both of which show chronic poor conditions that may be assumed to greatly inhibit the viability of a varied and healthy ecosystem.

The loadings of both ammonia and phosphate increase steadily downstream to Cranford Park, indicating that there are further inputs to the system, sufficient to overprint any capacity to remove, convert or sequestrate them.

In addition to the chronic conditions in the upper reaches there are also occasional peak outputs of both ammonia and phosphate at up to an order of magnitude or so higher than the background levels. (Note that these peaks can be seen in the individual site data plots presented in Appendix B). Some of these peaks are seen to originate at the top of the catchment (and seen in both tributary arms) although they can also be seen to propagate throughout the system to Site 12.

The concentrations of both ammonia and phosphate tend to decrease with distance downstream. In addition, at or below Cranford Park, the overall loadings also start to reduce. This latter feature is potentially indicative of the removal, sequestration or conversion of ammonia and phosphate occurring at a rate surpassing any downstream inputs.

The upper Duke of Northumberland's River provides a source of low ammonia water into the River Crane with a relatively high phosphate concentration. The phosphate levels (concentrations and loading) in the upper Duke's vary through the year.

Comparison of data from year one (May 2014 to April 2015) and year two (May 2015 to April 2016), indicate that the phosphate and ammonia levels in the upper reaches have increased year on year whilst the sources in the lower catchment have potentially reduced and/or the rates of removal/conversion/sequestration have increased.

3.0 RIVERFLY MONITORING INITIATIVE

3.1 Introduction

The RMI was developed by the Riverfly Partnership (www.riverflies.org) and launched nationally in 2007. It is now deployed by an estimated 1200 volunteers on over 80 catchments and 1000 sites across the UK.

The aims of the RMI are to:

- Increase catchment wide monitoring
- Detect pollution events and allow a more timely response to identifying sources of pollution by the Environment Agency
- Help map key problem areas that inform management of the river by the catchment partnership
- Develop a network of volunteers and groups that can link to other projects
- Raise awareness of issues impacting the river and empower local groups to take action

The River Crane's RMI scheme forms part of the Citizen Crane project, working with a network of citizen science volunteers to investigate water quality and ecological quality of the river throughout the catchment. A project team comprising Friends of the River Crane Environment (FORCE), The Zoological Society of London (ZSL) and Frog Environmental (FE) manage the project and undertake the analysis of the data. A steering group of the Crane Valley Partnership (CVP), Environment Agency (EA) and Thames Water help to co-ordinate the project and ensure it is linked into the wider decision making processes.

For more information on how the project has been set up refer to the Citizen Crane Year One report (CVP, August 2015). This Year Two report presents and analyses data collected during RMI sampling between May 2014 and May 2016. The RMI component of Citizen Crane Project was set up in 2014 with funds from the CVP, Thames Water fund. From March 2016 it has been funded by The City Bridge Trust.

3.2 Method

At the 11 sites shown on the map in Figure 1.1 RMI samples are carried out once per month by trained volunteers. 42 volunteers so far have attended a one day RMI training session at 4 separate training events in the catchment. Sampling at fixed sites includes a standardised three minute kick/sweep sample, followed by a one minute manual search of larger stones.

This method allows comparable samples to be taken over time. The RMI uses the presence and abundance of eight, relatively easy to identify, target groups of invertebrates (listed in Table 3.3.) as indicators of river health. Once a sample has been taken it is analysed on the river bank. Invertebrates relevant to the RMI are separated from the sample and counted. Their relative abundance is then converted into a score for the sample.

A score below a pre agreed 'trigger level' indicates that the river may be polluted and is reported to the EA's national environmental incident line.

3.3 Results

Between May 2014 and May 2016 a total of 218 samples have been taken, at the 11 sites shown in Figure 1.1. This is out of a possible total of 264 samples. Gaps in sampling have been caused by factors such as the unavailability of volunteers or heavy rain in the catchment causing unsafe river conditions.

Figure 3.1 shows the mean scores for each site over the reporting period. Newton Park West has the lowest mean score of 1, followed by Minet Country Park with 2.3. Mean scores are low throughout the upper catchment improving marginally to 4.2 at Yeading Brook Meadows and 5.8 at Donkey Wood-Crane. The Donkey Wood site is just upstream of the confluence with the upper Duke of Northumberland's River (upper DNR). The two sites downstream of this confluence, Crane Park Island and Mill Road Weir, show markedly improved mean scores of 8.6.

Newton Park West has also consistently breached its trigger level of 3 (see Figure 3.2). In 2015/16 the Volunteers at Newton Park West recorded a sample score of zero on 7 occasions. Two zeros were also recorded at Minet Country Park in summer 2015.

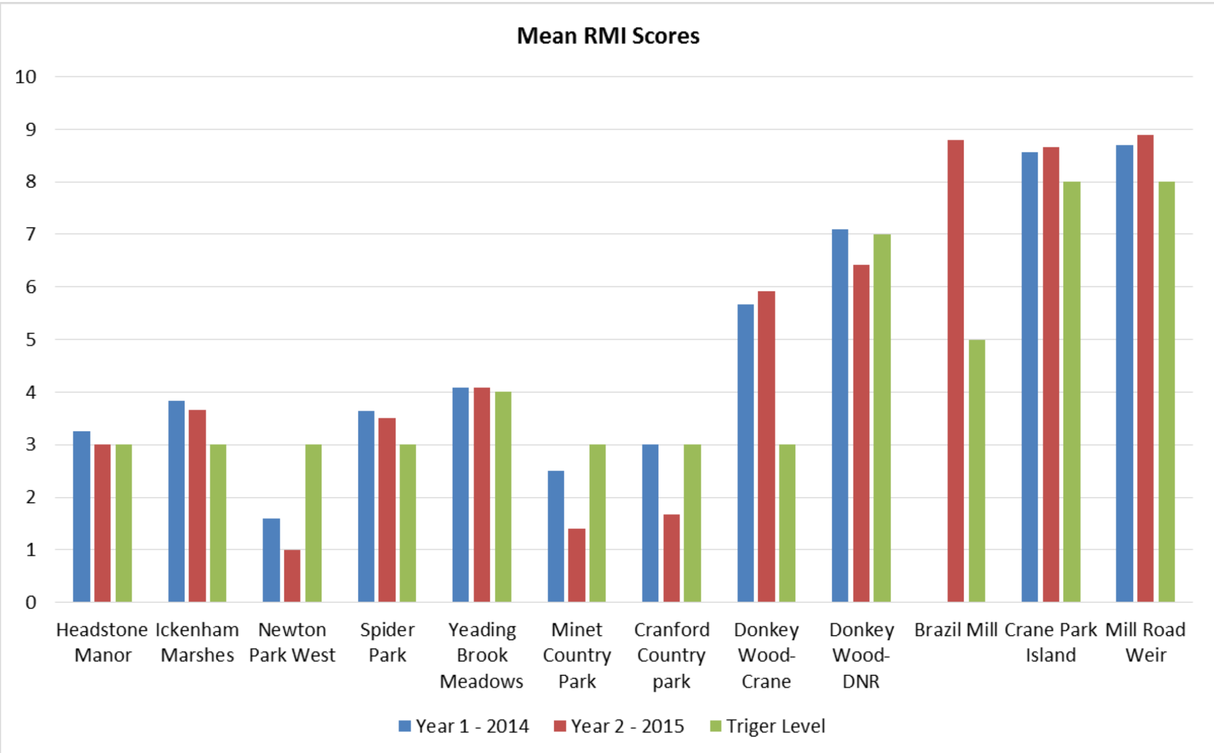

Figure 3.1 – *Mean RMI Scores by site*

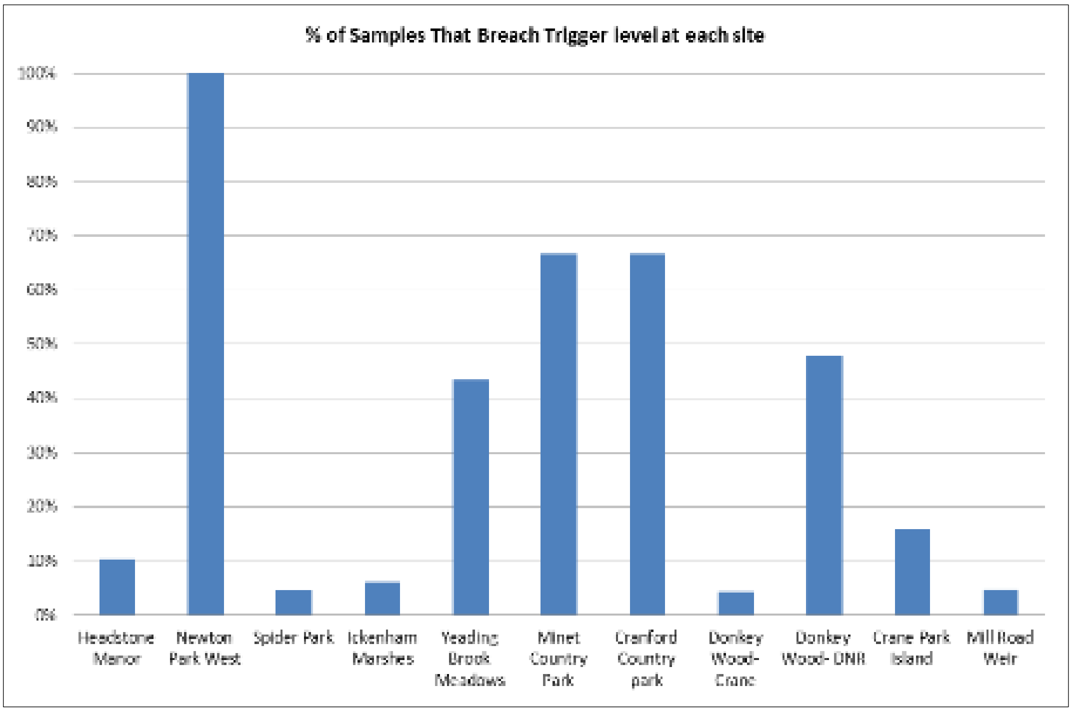

Figure 3.2 – *Trigger Level breaches as a percentage of the total number of samples at each site*

Table 3.1 – *RMI invertebrate groups recorded at each site during the period May 14 to May 16*

	Headstone Manor	Newton Park West	Spider Park	Ickenham Marshes	Yeading Brook Meadows	Minet Country Park	Cranford Country park	Donkey Wood-Crane	Crane Park Island	Mill Road Weir
Flat bodied mayfly (Heptageniidae)					✓				✓	✓
Mayfly (Ephemeridae)									✓	✓
Blue Winged Olive Mayfly (Ephemerellidae)				✓	✓		✓	✓	✓	✓
Olives (Baetidae)	✓		✓	✓	✓	✓		✓	✓	✓
Stoneflies										
Caseless caddis							✓	✓	✓	✓
Cased caddis	✓		✓		✓		✓	✓	✓	✓
Gammarus	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Total number of RMI groups found	**3**	**1**	**3**	**3**	**5**	**2**	**4**	**5**	**7**	**7**

The number of RMI invertebrate groups found in samples from each site, shown in Table 3.1, unsurprisingly follows a similar pattern to the mean scores by site. Greater invertebrate diversity, including the only records of true mayfly (Ephemeridae), has been recorded in samples downstream of the upper DNR. Gammaridae are the only group to be found at all sites and stonefly (Plecoptera) found at none. A total of three individual flat bodied mayfly specimens have been recorded from 3 separate sites, Yeading Brook Meadows, Crane Park Island and Mill Road Weir.

Appendix C includes all the RMI sample scores for each individual site over the reporting period.

3.4 Discussion

Over 400 volunteer hours have been spent sampling the river over the first two years of the Citizen Crane Project. An enormous added value of community monitoring, although hard to quantify, is derived from the increase in community understanding of river ecology and the sense of ownership and stewardship that typically develops in well managed citizen science projects (TCV, 2014).

Considerable value has been derived from the significantly increased frequency of monitoring and the improved synergy with the EA. The increased monitoring by the Citizen Crane network, for instance, has led to the early detection of specific pollution events that have in turn allowed the EA to respond quickly to problems. In the case of the Mill Stream event of October 2014, Citizen Crane reports allowed mitigation measures to be instigated within 48 hours of the pollution being detected, and EA investigations led eventually to the changing of polluting practices at several commercial operations.

In addition, the RMI data collected by volunteers provide a valuable baseline on which to build an increasingly detailed picture of the ecological quality of the river. The RMI methodology is a simplified, citizen science version, of the monitoring method used by the EA to check the ecological quality of rivers for Water Framework Directive classification. Invertebrate monitoring systems such as the Biological Monitoring Working Party (BMWP) (now updated to Whalley, Hawkes, Paisley, Trigg - WHPT) use the differing tolerances of invertebrate families to pollution, particularly organic pollution, to assess how degraded a river environment is. Animals with a higher score are more susceptible to pollution.

Table 3.2 shows the BMWP and WHPT scores (UKTAG, 2014) for the taxa used in the RMI method. In the case of Stoneflies, Caseless and Cased caddis these are not taxonomic families, therefore no appropriate fit with BMWP and WHPT scores exists. The scores are included here to illustrate the relative sensitivity of the RMI groups to pollution. With flat bodied mayfly and true mayfly being the most sensitive, and olives and gammarus the least.

Table 3.2 – *BMWP and WHPT Index values for the taxa used in the RMI method*

Group/family	**BMWP score**	**WHPT score for abundance 1-9**
Flat bodied mayfly (Heptageniidae)	10	8.5
Mayfly (Ephemeridae)	10	8.3
Blue Winged Olive Mayfly (Ephemerellidae)	10	7.9
Olives (Baetidae)	4	3.6
Stoneflies (plecoptera)	No score	No score
Caseless caddis	No score	No score
Cased caddis	No score	No score
Gammarus	6	4.2

Analysis of two years of RMI data shows that invertebrate communities in the upper part of the catchment are compromised and that the environment of these reaches is degraded, and severely degraded in the case of Newton Park West and Minet Country Park. Only the more pollution tolerant RMI invertebrate groups, Gammarus and Olives, are present in any significant numbers throughout the river. Other groups that are sensitive to degraded river environments, such as Caddisfly and Blue winged Olives, are recorded at only a few sites above the upper DNR and these records are infrequent and in low numbers.

When reviewing RMI data however it is important to keep in mind that complex relationships exist in rivers. Invertebrate communities are not only impacted by water quality but also geomorphology, water quantity and flow, shading, sediment quantity and quality. The RMI scores should only be taken as an indicative guide to ecological quality at each sample site. To get a better understanding of the exact causes limiting invertebrate communities in the upper sites, more in depth chemical and abiotic analysis is needed. The RMI data do though highlight the need to prioritise remediation and environmental improvement works in the upper section of the catchment.

4.0 OUTFALL SAFARI

4.1 Introduction

Citizen Crane water quality data indicate that phosphate and particularly ammonia, believed to be derived in significant part from surface water outfalls, are found at concentrations in the river that are damaging to its ecology. Misconnected domestic waste water pipework, cross connected sewers and combined sewer overflows are considered to be key sources of the chronic pollution load. Once in the surface water system, the pollution from misconnections enters rivers via surface water outfalls. Assessments of various databases by the Crane Valley Partnership (CVP) in 2014 identified 154 outfalls in the catchment. In 2015 Thames Water started a clean-up of 64 of these surface water outfalls as part of their regional Surface Water Outfall Programme (SWOP) due for completion in 2020.

The Outfall Safari (OSaf) was devised by the Citizen Crane steering group, following the Citizen Crane Outfall Monitoring Feasibility Study conducted between May and August 2015 (report available from CVP website http://cranevalley.org.uk). The aims of the OSaf are to:

- Record and map the dry weather condition behaviour of surface water outfalls across the Crane Catchment
- Develop a low cost method (incorporating an App) that can be used periodically in the catchment to inform ongoing catchment management decisions. In particular to help identify (and potentially prioritise) outfalls for inclusion in the AMP 7 Thames Water Surface Water Outfall Programme (SWOP), due to start in 2020
- Further engage the existing Citizen Crane network and recruit more volunteers in the delivery of the Catchment Management Plan

4.2 Method

4.2.1 Overview

The survey of outfalls was conducted between May 16th and June 23rd 2016. This time period was chosen as it was predicted to provide the best chance of lower rainfall in the catchment and also was hoped to be in advance of abundant riparian plant growth that can make outfalls difficult to see. Seventeen people took part in the OSaf, comprising 13 Citizen Crane volunteers, two Environment Agency staff and two ZSL staff. Volunteers were trained during two separate training events. Training included:

- An overview of water quality issues in the Crane catchment
- Information on outfalls and how they become polluted
- Instruction on how to assess each outfall using the project App and upload information to the database
- A health & safety briefing and signing of the risk assessment.

During the training, groups of volunteers were assigned lengths of river to survey. They were free to conduct the survey of their reach when convenient, within the survey period, provided there had been no rain for 48 hours prior to survey. A period of 48 hours of no rain is required before any survey work as rainfall and high surface water flows can obscure the negative impacts of outfalls by washing away sewage fungus, discoloured sediments and rag.

The majority of the survey work (approximately 20 km) was conducted from the riverside path, with the occasional need to enter the river to properly assess and photograph an outfall. The risk assessment for riverside outfall surveying highlighted the need to assess conditions in the river before entering it and stressed that volunteers should only get in if the level was lower than Wellington boot depth. During the training volunteers were also shown images of Giant Hogweed (*Heracleum mantegazzianum*). It was essential that volunteers could identify Hogweed before undertaking any survey work as it is a relatively common plant along the banks of rivers in London and can burn and blister skin if touched.

In some reaches of the river, where it flows through private land or is inaccessible from the banks, the survey had to be conducted in-channel. On these surveys more stringent health and safety rules applied. Waders, stabilising poles and life jackets were used by in-channel survey teams (see Figure 4.1). EA staff and Local Authority infrastructure teams were consulted to be sureall tributaries in the catchment were identified and accessible. Some, such as Brook Drive channel (shown in Figure 4.1), are only found on specialist maps. Approximately 14 km of the river were surveyed from within the channel making the total length of river surveyed, 34km.

In addition to personal protective equipment volunteers took a printed handout, designed to help with ranking the impacts of each outfall, and a smart phone or tablet loaded with a specially created data entry App.

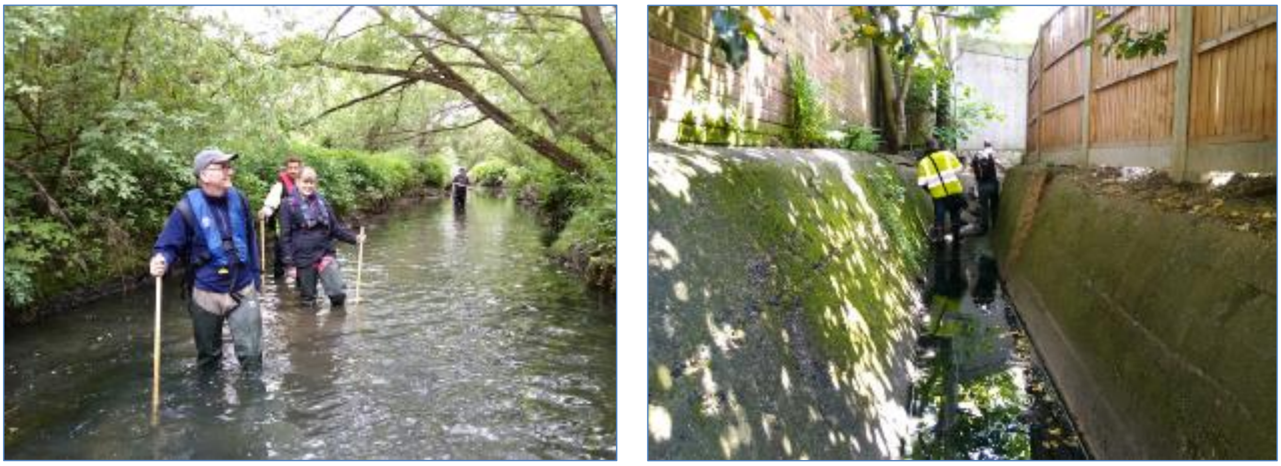

Figure 4.1 – *In-channel survey work at A, Minet County Park and, B, Brook Drive, Harrow during the 2016 outfall survey*[2]

[2] *Source: ZSL*

4.2.1 The App

For ease of data collection from the river, the project team created an App using Epicollect plus (plus.epicollect.net). Created by researchers at Imperial College, Epicollect is free and openly available. Once a project is set up in Epicollect it provides an App for remote data collection and upload, usable on GPS enabled smart phones, and a web portal to access and download the data. The outfall assessment form created in the App consisted of eight questions for volunteers to fill in at each outfall. The questions were taken directly from the form that Thames Water use for assessing the impact of outfalls and are shown in Table 4.1.

Table 4.1 – *Questions used in the Epicollect App to assess each outfall and their corresponding Impact Score*

Question	Options	EA score
1. Volunteer name 2. Date of Survey 3. GPS location 4. Photo of the outfall 5. Description of the nearest landmark		
6. Ranking of the flow coming out of the outfall		
	a. No Flow	
	b. Trickle	
	c. Low Flow	
	d. Moderate Flow	
	e. High Flow	
7. Ranking of the visual impact of the outfall		
	a. No visible effect	0
	b. With 2m of outfall	2
	c. Impact 2 to 10m	4
	d. Impact 10 to 30m	6
	e. Impact greater than 30m	10
8. Ranking of the aesthetics of the outfall		
	a. No odour or visible aesthetics	0
	b. Faint smell, no visible impact	2
	c. Grey water foam of scum	4
	d. Strong smell, sewage fungus or litter	6
	e. Faeces, gross litter or fungus	10

4.2.2 Conversion of outfall assessment to impact scores

In order to allow prioritisation of the outfalls, the EA provided a method of converting the assessment data to a numeric impact score for each outfall. These scores are shown on the right hand column in Table 4.1. Any outfall with an impact score of 10 or more, from the options in questions 7 and 8, was deemed by the project steering group to be polluting and was therefore reported into the EA's National Reporting System (NRS) during the survey.

4.2.3 Data Processing

Outfall data were checked to remove double entries and mapped using QGIS Desktop 2.12.3.

4.3 Results

The volunteers photographed, located and assessed a total of 227 outfalls, compared to the 154 identified in the 2014 survey. Of this total 64 (28%) showed signs of pollution. The locations of all assessed outfalls are shown in Figure 4.2. The colour of the dots shown in the map reflects the impact score for each outfall. These plots can also be studies in more detail on the Crane Valley Partnership web-site www.cranevalley.org.uk

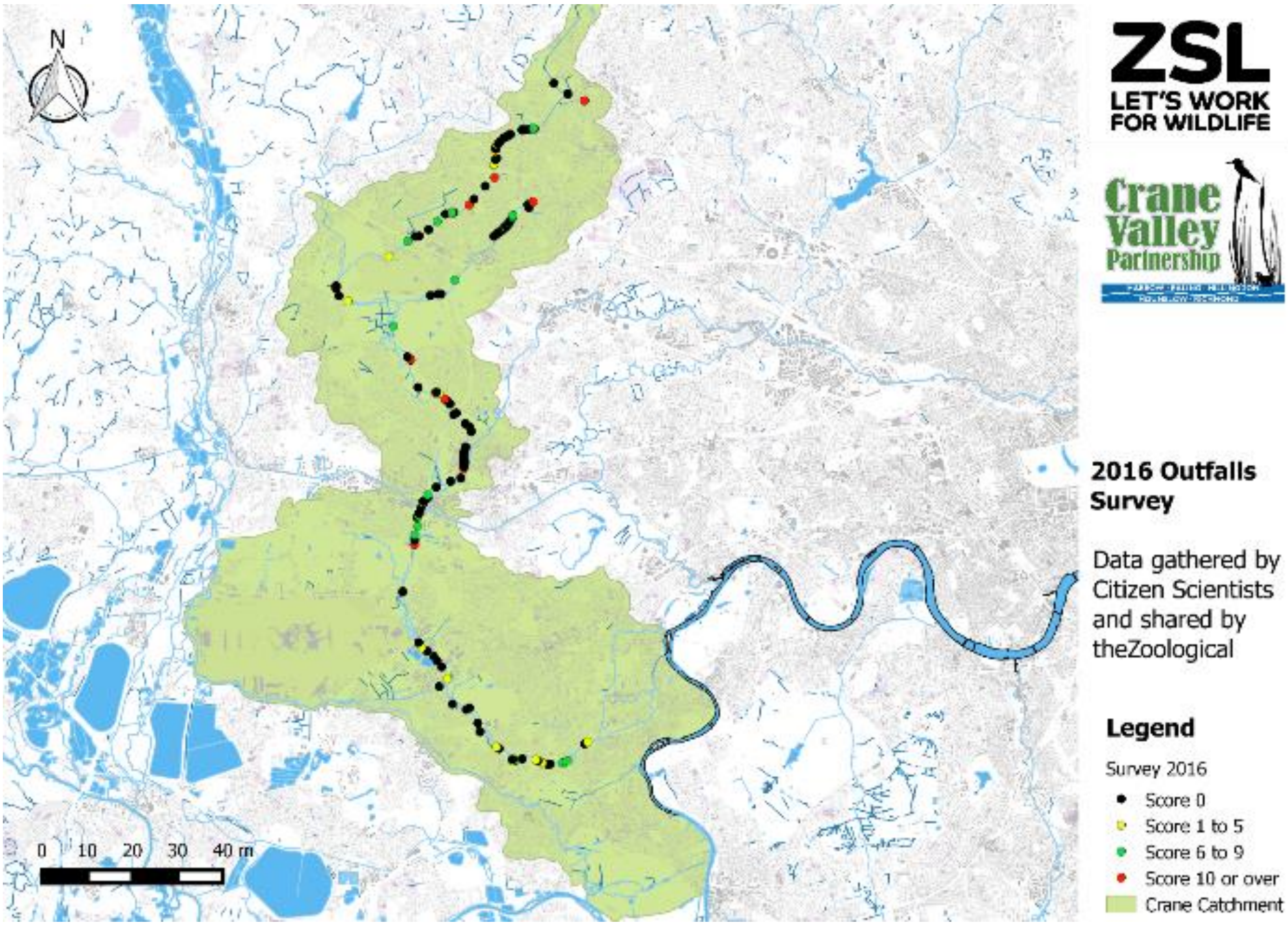

Figure 4.2 – *Map showing all outfalls recorded and assessed during the OS and their colour coded assessment score banding*[3]

[3] Source – ZSL

Table 4.2 – *The numbers of outfalls recording each score above zero*

Impact Score	Number of Outfalls
20	1
16	2
12	1
10	4
8	14
6	16
4	9
2	17

Of the outfalls assessed, 163 (71%) had an impact score of 0. Table 4.2 lists the number of outfalls for each impact score between the lowest possible score of 2, and the maximum score of 20. More details of the 38 outfalls given an impact score of 6 or above are shown in Appendix D.

4.4 Discussion

The survey had the immediate positive impact of increasing collaborative working with the EA and Thames Water by building capacity to monitor pollution sources on the river and by using system designs collaboratively by the Citizen Crane steering group, which includes EA and TW. Other initial benefits from the work are:

- The 8 outfalls reported to the EA NRS, with impact scores of over 10, are now being investigated by EA staff
- Thames Water are using the OSaf data to help re-prioritise SWOP works in the catchment
- Photos now exist of all outfalls recorded during the OSaf, 2016
- A methodology has been created and can be refined for future use
- The methodology is already being adopted by other catchment partnerships within London

4.4.1 Suitability of the survey method

To the best of our knowledge this was the first time this type of survey has been run as a citizen science project. In order to assess the suitability of the method for future surveys on the Crane, and potentially other catchments, the recorded data have been compared to existing outfall datasets here. Two existing datasets have been made available to the Citizen Crane team:

- Crane Valley Partnership (CVP) 2014: These data have been derived from a combination of an MSc student's survey of the river, EA and TW data
- EA 2013: These data were derived from a survey led by EA staff

The numbers of outfalls recorded in the three datasets are shown in Table 4.3.The survey areas included in each dataset differ so they cannot be directly compared, for instance the OSaf 2016 did not include the Crane downstream of Mereway Weir and any of the Upper Duke of Northumberland's River whereas the CVP 2014 dataset includes these areas.

The number of outfalls recorded by OS 2016 is most likely considerably larger than CVP 2014 as volunteers applied themselves rigorously to the task recording all outfalls, no matter how small. It is suspected that a number of the small 'unofficial' outfalls have probably not been recorded before and do not show on drainage maps.

Table 4.3 – *The number of outfalls recorded by the EA in 2013, CVP in 2014 and the Citizen Crane OS in 2016*

	EA 2013	CVP 2014	OSaf 2016
Total outfalls	**103**	**154**	**227**
Outfalls (Crane)	36	100	110
Outfalls (Yeading Brook East)	13	34	55
Outfalls (Yeading Brook West)	54	20	62

Ideally there would be a detailed comparison of the OSaf 2016 data with previous data sets in order to check if volunteer surveyors taking part in the 2016 OSaf missed outfalls that have previously been recorded by others. This would give an insight into how effective volunteer surveys from the riverbank are at recording all the known outfalls. However, variability in GPS accuracy/location data caused uncertainty when comparing the OSaf data with other datasets. Some of the volunteers did report that dense riverside vegetation prevented them from accessing some sections of river which may have caused some outfalls to be missed.

4.4.2 Comparison between OSaf 2016 data and Thames Water's SWOP list

Information from the EA 2013 survey informed TW's current SWOP works to clean up 64 PSWOs in the catchment. In order to inform the discussion around the prioritisation of the on-going SWOP work Thames Water compared the 38 outfalls that scored 6 or above to outfalls on the SWOP list. Thames Water's notes are included in the right hand column of the table, which is shown in Appendix C.

4.4.3 The suitability of the assessment questions and survey protocol

A number of issues have been flagged up during the Outfall Safari. These are set out below with a view to improving the procedures for future events in the Crane and elsewhere:

<u>GPS location</u>

GPS accuracy is variable, dependent on the quality of the hardware in the mobile device and how built up the area is at the location point. This was a particular problem when comparing OS 2016 data with previous datasets and trying to match 2016 data records with outfalls on the TW SWOP, as GPS data for outfalls don't always match.

More clarity on where the surveyor is in relation to the outfall would help with data processing. 'Are you on the same bank as the outfall?' as additional question in the App would help for instance. In addition, during future training it will be important to stress the need to get as close to the outfall as possible when recording GPS data.

Description of the nearest landmark

It would be helpful in the future to be more prescriptive about what location data are needed. This question can be broken down into:

- Which bank is the outfall on?
- What is the nearest road?
- How many other outfalls can you see at this location?

Ranking the aesthetics of the outfall

The available answers for this question proved problematic as they did not always represent what could be seen at the outfall. One scenario that did not fit the available answers, for instance, was when there was sewage fungus on the sill of the outfall but the discharge was running clear. One suggested way of getting round this issue was to provide a check list of features of the outfall e.g. colour, smell, rag etc. rather than aggregate descriptions.

Long term outfall monitoring on the river (see section 5 below) has shown that outfall behaviour can change quite dramatically in a short space of time - particularly after heavy rainfall – and therefore this survey methodology would not be the best for detecting outfalls with intermittent discharges.

4.4.4 Assessment of the App

The App has some limitations. It is not compatible with Microsoft smartphones and several volunteers could not download it to their android phones. Volunteers were provided with a handout that included images and descriptions to help with ranking of the flow and aesthetic impact but it would be more helpful if images of examples of different impacts could be integrated into the App itself. This might help reduce variation in reporting the more subjective elements of the outfall assessment. Other open source options that have the same functionality that could be adapted for use on an outfall survey include: fieldtripgb.blogs.edina.ac.uk.

4.5 Conclusions

The OSaf has proved helpful in recording the dry weather condition behaviour of surface water outfalls into the river system and reporting the most severe sources of pollution into the Crane and Yeading brooks at the time of the survey.

The value of the OSaf could be improved however by improving comparability of different datasets. One idea to enable this would be to create a photo catalogue showing outfalls with unique identity codes. The Crane Catchment Partnership Host and EA are considering how best to do this.

5.0 LONG TERM OUTFALL SURVEYS

5.1 Approach to the Long Term Surveys

Selected Citizen Crane teams started to monitor the status of the surface water outfalls local to their sites in summer 2015 with the intention of testing the feasibility of a focused investigation into outfall conditions. Sites 2, 6 and 12 were included in this pilot study and the detailed findings of this work were reported in "Citizen Crane Outfall Monitoring Feasibility Study – October 2015". One of the key outcomes of this work was the 2016 Outfall Safari project reported in Section 4.0 above.

This work has continued in the lower Crane (around Sites 11 and 12) until present, and has allowed longer term data to be collected about key surface water outfalls along a 3 km reach of the river within Crane Park in LB Richmond and LB Hounslow. A significant number of these outfalls have been included in Thames Water's surface water outfall programme (or SWOP), designed to remove misconnected domestic appliances from the surface water drainage system.

Data were collected on a monthly basis, by visual assessment of the conditions at each outfall, including an estimate of the flow rate. For the first few months an assessment was carried out at every outfall in the sector, although with time the focus was narrowed to those outfalls known to be problematic and/or on the Thames Water SWOP. Occasional water samples were taken for TW laboratory analysis, so as to supplement these visual records with concentration and loadings data for phosphate and ammonia.

5.2 Results from the Long Term Surveys

These surveys have allowed the development of an improved understanding of the nature of surface water outfalls and their impact upon the river environment. The key findings are recorded below:

- There are ten surface water outfalls in the 3 km within Crane Park (around and upstream of monitoring sites 11 and 12) that have been included in the Thames Water surface water outfall programme (SWOP)
- The average outflows from these outfalls varied from around 0.3 l/s to 3l/s. Outflows continued, though at a reduced rate, throughout dry weather periods, indicating that the drainage systems in this part of the river intercept the water table and are acting as groundwater drainage as well as urban rainfall drainage.
- The outfalls all had a characteristic sewage fungus covering on their concrete apron prior to any SWOP works, indicative of high nutrient concentrations in the run-off. EA specialists have noted that this sewage fungus will only remain present for a matter of days in the absence of the nutrient load that sustains it. In addition, the outfalls were often noted as having sewage or detergent smells associated with them. Occasional spot sampling from the outfalls indicated the concentration of phosphate and ammonia was typically 1 to 2 mg/l phosphate and ammonia

- Of most concern, several of the outfalls had occasional plumes of grey-brown, sometimes rag rich and foul smelling water, extending between 5 and 30 metres into the main river. These "flare ups" might last from a few hours to one or more days and were often reported to FORCE and others by local people. These flare-ups were sometimes, but not always, associated with rainfall events. The worst offending outfall (at Hospital Bridge Road) displayed these flare ups every couple of months or so even during and after extensive SWOP investigations
- The total outflow from the outfalls on the SWOP in this area is in the order of 10 to 15 l/s, resulting in background loadings into the river of around 1.5 kg/day, of both phosphate and ammonia. This is around 15 and 40 per cent respectively of the total loadings in the river at this location
- The SWOP has been active on many of these outfalls over the last two years. Typically the contractors found between 15 and 35 misconnected facilities on each outfall – including several toilets and large numbers of showers, hand basins, dish washers and washing machines
- Around 80 to 90 per cent of these misconnections were reported as being rectified by the home owner (or Housing Association), following an initial approach by Thames Water, with the remainder being referred to the council's Environmental Health Office for follow up
- Several of the worst performing outfalls have now been signed off by Thames Water, and subsequent field visits indicate there is little or no sewage fungus associated with them any longer. One outfall (Hospital Bridge Road) has proved more difficult to rectify, with continued problems of sewage fungus, high nutrient loads from spot samples and occasional pollution plumes being recorded. Further works by contractors have found additional misconnections and Thames Water do not believe there are any cross connections into the sewer system linked to this outfall
- In general the SWOP process takes a few months to complete – although where there are recurrent problems such as at Hospital Bridge Road it may take one or more years
- The loading data indicate these improvements in outfall performance are of sufficient magnitude to be recognised in the river monitoring data, particularly with respect to ammonia, where a 40 per cent reduction in river loading might be expected if the SWOP were 100 per cent successful

These findings are made, subject to review and discussion with Thames Water.

5.3 Conclusions from the Long Term Surveys

The long term surveys are providing a valuable insight into the impact of polluted surface water outfalls on the nutrient loadings of the river system.

The lower reach of the river, around Sites 11 and 12 within Crane Park, has been the focus of these long term studies. This reach has also had most focussed investigation and remediation by the Thames Water SWOP teams. It has therefore been possible to develop an understanding of the potential benefits of the SWOP.

The polluted SWOP outfalls showed "background" levels of phosphate and ammonia (in the order of 1 to 3 mg/l), with moderate to high levels of sewage fungus on the outfall apron. Several of the outfalls also displayed occasional flare (lasting from a few hours to a day or two with extended plumes of grey brown water indicative of raw sewage.

The typical polluted outfall may have between 15 and 35 misconnections, including sewage sources as well as washing water, providing a chronic nutrient load. It is possible that some drainage systems, such as Hospital Bridge Road, contain voids and/or blockage points which can fill with solid materials during lower flow periods, only to be flushed or unblocked every month or so.

The SWOP programme appears to have been largely successful in remediating the polluted outfalls, albeit that some outfalls may require repeated investigations to fully resolve. The successful resolution of these problems may have reduced the loadings of phosphate and ammonia into this reach of the river by 15 and 40 per cent respectively, over a 2 year period.

The monitoring of these SWOP outfalls by the citizen science teams has had the following benefits:

- Field information has been provided to Thames Water on a monthly basis regarding the performance of the programme
- Much improved public awareness of the SWOP work and the issue of misconnections more generally. Around 2000 information leaflets have been given out by Citizen Crane volunteers and there have been regular Facebook postings by volunteers and members of the public – including regular reports of pollution problems
- Identification of several pollution incidents – including illegal disposal into road drains for example
- Linkages provided between the Thames Water programme and the councils' parks departments and environmental health teams.

These benefits have supported the effective engagement of the SWOP contractors, and may have also improved public awareness and the consequent misconnections clear up rate.

It is notable that those members of the public that use Crane Park regularly are much more aware of the misconnection issue than when the project started. The park is well known and well used by local people and the ready association between the misconnected property and the park may have helped with the response rate to problems when found by the SWOP teams. In other parts of the river, where there is not such a clear connection between the misconnection and the local environment, the response rate may be much reduced.

6.0 REAL TIME MONITORING

6.1 Approach to Real Time Monitoring

Real time monitoring is carried out using sondes, deployed in the river and typically set to collect a range of water quality data at 15 minute intervals. This project has not carried out any real time monitoring of its own to date. However, the project team has taken the opportunity to engage with the Environment Agency (EA) and Heathrow Airport Limited (HAL) operatives, both of which have deployed sondes in the River Crane over the project period. The Citizen Crane team has been given access to some of these data, and reviewed them with the EA/HAL project teams, to develop an improved understanding of the chemical nature of the river in space and time.

HAL has been using real time sondes to monitor the water quality upstream and downstream of its main surface water outfall into the River Crane for at least five years. These sondes collect data at 15 minute intervals on conductivity, turbidity, ammonia, dissolved oxygen and temperature. The project team looked at the data from the sonde upstream of the Heathrow outfall, located above the upper Duke of Northumberland's River confluence and around a kilometre upstream of Citizen Crane Site 9.

An initial meeting was held on 19th April 2016 between HAL, the EA national monitoring team (based in Reading – who are running HAL's system) and the project steering group. The data were looked at and initial interpretations made of the data findings. A follow up meeting was held on 3rd June between the national EA team and the project team to further interrogate the data and draw some further preliminary conclusions.

Requests have been submitted to HAL for formal release of the data set for the upstream sonde to allow a further detailed analysis and illustration in this report. Formal permissions have not been received to date and in the interim the conclusions based on these initial data review meetings are presented in Section 6.2 below.

The Environment Agency at an area level has been carrying out real time monitoring in the upper Crane catchment in 2016 as part of a pollution investigation. The EA has released data for the sonde upstream of the possible pollution source to add to the Citizen Crane data set. The sonde was installed at Ruislip Gardens on the Yeading Brook west and close to Citizen Crane Site 2.

The data for conductivity, ammonia and dissolved oxygen, recorded between 10th March and 9th April 2016, are shown in Figure 6.1 below.

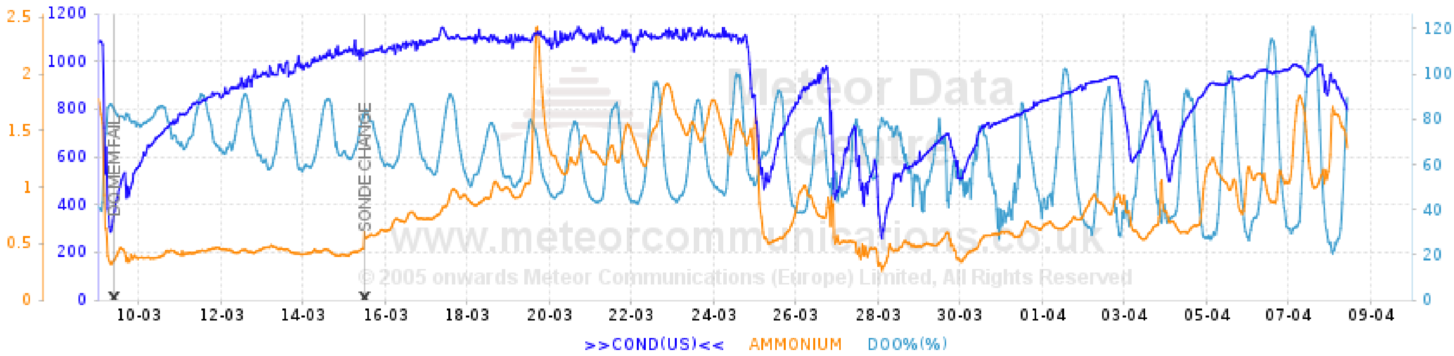

Figure 6.1 – *Screen shot of real time data from monitoring station at Ruislip Gardens*

6.2 Findings from the Real Time Monitoring

The initial findings from the HAL data include:

- There is a marked diurnal variation in the dissolved oxygen (DO) levels in the river. Maximum levels are recorded before sundown and minimum levels just before sunrise
- This diurnal variation in DO ranged between 110 and 70 per cent in March 2016
- In early April the DO level was varying daily between 120 and 50 per cent. However, over the next few weeks the level dropped steadily so that by early May the daily variation was between 50 and 20 per cent
- This large diurnal variation is considered to be a function of a high nutrient system with high concentrations of benthic algae that give out oxygen during the day and remove it at night. By contrast a low nutrient system may be expected to vary between 100 and 80 per cent for a longer part of the year
- The steady reduction in DO over the period from early April to early May correlates with a steady slow increase in both ammonia concentrations and conductivity (likely to be due to reduced flow), and an increase in water temperature from around 11 to 18 centigrade, all related to the extended dry spell in late Spring 2016
- On the morning of 10th May there was a storm event in the catchment. DO levels were recorded as falling to around 10 per cent on the night before the rainfall started. This may be a function of the low pressure system in advance of the storm allowing DO to leach from the river
- As the storm event continued through 10th May the DO continued at a low level of 10 per cent through the day, with no daytime recovery of oxygen levels. This is indicative of significant organic enrichment in the water column leading to a high oxygen demand. Resuspension of sediment may have also contributed to both an increase in BOD (resulting in more oxygen being lost) and reduced light penetration (resulting in less oxygen being generated)
- These low DO levels continued for over 24 hours, creating toxic conditions for the river ecology. This combination of events during a summer storm can cause fish kills, and there have been fish kills in the Crane during similar events in the past. There were no fish kills reported during this event however. This may have been due to the availability of a more oxygen rich part of the river for fish to move into and/or the relative absence of large fish (following the 2011 and 2013 pollution kills), with any kill among the smaller fish not being seen

- Invertebrates are not as mobile as fish and this event may have caused significant kills among the invertebrate population of the river at this, and likely at other, locations. Any large scale losses caused by this type of event would probably be picked up by subsequent RMI sampling. Note: the data presented in Appendix C herein only extend to March 2016
- By 11th May daytime DO levels had recovered to around 30 per cent and the system slowly recovered to pre-storm variations over the following week
- Another feature of the overall dataset was short term spikes in ammonia concentrations lasting a few hours. These peaked at 1 mg/l or more, compared to the baseline level of around 0.3mg/l. One such peak was noted during the storm event of May 2016, and there were other peaks recorded one or more times per month, not all of which correlated clearly with storm events. N and P spikes arising from run off from salting roads have been known to mimic an ammonia spike after a storm event, as stated by the Environment Agency representatives in the meeting of 19th April
- HAL has been using the data set to identify winter inputs of glycol (or similar) into the river system above the Heathrow outfall. The source of these inputs is not yet known
- The HAL data also provided a clear record of the impact on the river system of the major pollution events of October 2011 and October 2013

These data reveal the great value of real time monitoring in developing an improved appreciation of the variations in water chemistry with time.

An initial review of the EA data, as shown on Figure 6.1, indicates the following:

- The diurnal DO levels in early March varied between 80 per cent and 60 per cent
- Minimum DO levels reduced fairly steadily through the month such that by early April the minimum night time DO had reduced to 20 per cent
- Conductivity levels are a good indicator of the dilution within the system. On this basis it would appear that there was an initial input of fresh rainwater run-off into the system in early March (with conductivity levels reducing to 400) and another couple of rainwater inputs in late March and early April
- Ammonia levels were around 0.5 mg/l in early March, and rose steadily to around 1 to 1.5 mg/l by early April. These may also be indicative of the degree of dilution in the system
- There were several short term peaks in ammonia levels, comparable to those recorded on the Heathrow sonde (and noted above). One in particular, around 20th March 2016, showed a doubling of ammonia from 1 to over 2 mg/l, for several hours.

These data are comparable to those from the Heathrow site. Further consideration of these data is given below in the discussion of results.

6.3 Conclusions from the Real Time Data

The data seen to date are only partial in both time and space, with only two sites and two months’ data looked at in any detail. However they are sufficient to both reveal the great potential of real time data as an investigative tool and provide some early insights into the detailed chemistry of the river, as follows:

- The diurnal variations in DO are present in both datasets, increasing in intensity as the weather becomes warmer into the spring and summer. The effect appears greater in the upstream site, indicative of more nutrient enrichment
- In both cases the oxygen sags indicate conditions that would be injurious to some river life for at least part of the time. This may be an insight into the challenging conditions in the middle and upper parts of the river for aquatic fauna
- Both data sets contain short term peak ammonia levels, over several hours and at two to three times the baseline level, one or more times each month. These features are indicative of intermittent discharges of effluent into the river that represent a further challenge to the ecosystem. Some of these spikes may also arise from false readings when de-icing agents run off into the river (as discussed in Section 6.2).

Whilst these data are not definitive, there is sufficient value in them to support the case for further and targeted monitoring of the river in the future to better understand the spatial and temporal dynamics of the system.

7.0 OTHER CATCHMENT OBSERVATIONS

A considerable added benefit of the two years of volunteer led data collection, and in particular the outfall safari, has been the field visits to parts of the river that had not previously been seen by the project team. A number of field observations have been garnered as a result, feeding into the developing understanding of the river system. These are set out below, starting at the top of the catchment:

- There are four small and largely culverted drainage catchments feeding into the top of Yeading Brook West in Harrow. Two of these feed into the moat at Headstone Manor and, when visited in June 2016, the water in the moat was grey and appeared anoxic. A local volunteer noted that the moat had been dredged 3 times in the last 20 years and this proved very expensive due to the polluted nature of the sediment. A site calculation estimated there may be 2000 cubic metres of polluted sediment in the moat at present
- One of these four drainage catchments runs in an open culvert, several hundred metres in length, along the back of private properties in Headstone Gardens, only accessible behind fences with a council key (see Figure 7.1). At least one hundred metres of this culvert was covered in a thick layer of sewage sludge, when visited in late May 2016, and the total volume of sludge held there was in the order of 20 cubic metres
- The sludge held in this open culvert would have a significant impact on the condition of the river downstream if and when it was flushed out. This type of configuration may explain some at least of the peak nutrient loadings, that have been recorded in the water quality data sets and observed at other outfalls in the catchment
- The upper reaches of both Yeading Brook East and Yeading Brook West emerge from large culverted sections beneath housing estates. The outfall from the main culvert on Yeading Brook East is evidently receiving considerable amounts of polluted water, to judge by the strong odour and large amount of rag on the outfall bars. This is supported by the water quality data from Site 4 around half a kilometre downstream
- These findings have been reported to Thames Water through the project steering group and have resulted in additional focus being put into investigating and resolving the root causes through the SWOP programme
- The two small tributaries both flow through housing estates, parks and other public open spaces such as Ickenham Marshes. The streams appear relatively natural in character along these reaches although they are over-shaded in places
- Further downstream, above and below the confluence of the two tributaries, works are being done (by LWT and others) to improve the character of the streams, by channel narrowing and increasing the sinuosity of the system
- The middle reaches of the main river, above the confluence with the upper DNR, are slower moving and many parts are in a heavily engineered condition – straightened, widened and/or deepened and heavily shaded by tree cover. Large parts of this section are secluded from public view. There is little or no in-stream or marginal vegetation and the river bed is typically covered with algal growth. In reaches such as Minet Country Park, where the channel section has been over-deepened, there are deep accumulations of anoxic sediment

- The reaches immediately above the Upper Duke's confluence – and continuing below for around 6 km to the lower Duke's River at Kneller Gardens - are generally in a better condition, particularly where local management has reduced the tree cover, and instream works have narrowed the river and created a higher energy sinuous low flow channel. River vegetation such as ranunculus has thrived in many of these areas, further narrowing the active stream channel and flushing any sediment and/or algae from exposed river gravels
- The river divides at Kneller Gardens below Site 12, with much of the low flow being carried along the lower DNR. The Crane channel was widened, straightened and deepened as a concrete lined conveyer channel for flood flows in the 1930's. This channel receives little or no flow during low flow conditions. This channel is tidal over the last couple of kilometres above the confluence with the Thames, where it is less canalised and more natural in character
- The lower DNR is an artificial channel constructed in the 1500's and is maintained with a regular flow by the operation of Meadway sluice. As a result it has developed into a high value linear ecosystem with no flood flows and little input from surface drainage. It was not included in the 2016 Outfall Safari

These observations feed into an overall understanding of the river system which is set out in Section 9.0.

Figure 7.1 – *Drainage channel to the rear of Headstone Gardens*

8.0 STAKEHOLDER ENGAGEMENT

One of the benefits of the Citizen Crane project is the way in which it has facilitated a wider engagement with both local communities in the catchment and a wider community of those interested in river management. Examples are provided below:

- The most important interaction is with the Citizen Crane teams themselves. Over 40 volunteers have been trained, and representatives go monthly to each of the eleven monitoring sites to collect data and samples. These teams are also the “eyes and ears” on the ground, identifying problems and proposing solutions to local river issues. The teams also provided many of the volunteers for the Outfall Safari
- The key professional interaction is with the Citizen Crane steering group, comprising representatives from Thames Water, Environment Agency and Green Corridor (Crane Valley Partnership co-ordinators). This group provides practical and technical support to the project. They also seek to use the information provided to adapt and enhance their work protecting and improving the condition of the river system
- There is considerable engagement with the general public during the monthly sampling exercises, generally held in a public open space over an hour or so during the weekend. By this means it has been possible to disseminate information about the quality of the river system and the impact of misconnections, as well as receive information from the public based on their observations
- Around 2000 Citizen Crane leaflets have been distributed during the last two years, many to the general public, as well as to attendees at various meetings and other events
- Social media has proved valuable as a way of disseminating information on the project and gathering public information on pollution problems and related issues of concern
- A short film has been commissioned by the team to illustrate the Citizen Crane project and will be launched at the annual Citizen Crane forum in November 2016. The project also features in another video, produced by ZSL, on citizen science projects across London
- The project has good links with a number of Universities (including St Mary’s University, Brunel, Royal Holloway and Kingston for example). Technical experts have contributed to the project, and helped to develop approaches and review findings, whilst undergraduate and post graduate students have undertaken investigations and theses, using base data from the project and helping to expand the project findings
- The project has been presented to various regional and national groups such as “Catchment Partnerships in London”; the DEFRA funded “Catchment Based Approach” group; National RMI Forum; the River Restoration Centre’s annual conference; and the “All London Green Grid” group. The forums provided an opportunity to exchange ideas and approaches with other groups and partnerships. Several project elements (such as the outfall safari app) have been adopted in this way, and several London based river groups are proposing to adopt elements of the project, including their own Outfall Safaris, over the next year

These interactions are key to the success of the project, and are also helping to export project ideas to other catchments around the country.

9.0 AN OVERVIEW OF THE FINDINGS

The data and observations gathered through the Citizen Crane project have helped to develop a much more detailed picture of the river system and how it operates. The broad conclusions with respect to each part of the river system are set out below, followed by an assessment of potential causes.

9.1 Upper tributaries

There are major and broadly comparable issues in both upper tributaries of the river. There are major sources of phosphate, and particularly ammonia, coming into these upper reaches from the culverted drainage catchments above.

The data show a baseload of several kg/day coming into the top of these tributaries, as well as peak inputs an order of magnitude higher than this. This finding is reflected in the real time data sets, which show occasional (once a month or more) ammonia peaks in the upper and middle reaches.

The high baseloads of ammonia and phosphate are indicative of chronic misconnection problems in these upper drainage catchments, which are largely culverted and not easily identified. There may also be further network issues and blockages contributing to the baseload. In addition, the peak loadings may be caused by local stores of sewage sludge which settle out in ad hoc flow traps within the system (as was witnessed in the open culvert behind Headstone Gardens - Figure 7.1 above) and then flush out, as and when flows increase or some barrier is overwhelmed.

The chronic condition of the moat at Headstone Manor, and the enormous volume of anoxic sediment held within it (in the order of 200 cubic metres), are indicative of the scale of the problem in the upper reaches of Yeading Brook West.

As a consequence, these tributaries, despite being geomorphologically interesting and often running through attractive suburban parks and gardens, have little life within them and typically score only around 1 to 3 on the RMI system. It is an added concern that the nutrient loadings in this part of the river system are significantly higher in year two than in year one.

9.2 Middle Reaches

The middle reaches of the river have a reducing phosphate loading but an increasing ammonia loading. A number of significant polluting outfalls were identified along this reach during the Outfall Safari. The loading from the upper reaches is also continuing to have an effect, as a source of both long term chronic pollution and occasional higher concentration inputs.

Large parts of these reaches are also subject to poor geomorphology, having been straightened and over–deepened in places, and often shaded out with little or no maintenance. The substrate as a consequence is often either anoxic silt, or algae covered gravel, with little or no in-stream vegetation.

Both sets of real time monitoring data are records of the condition in these reaches. The anoxic silt and algae cover may account for the high diurnal variations in dissolved oxygen recorded in these data. Night time levels of dissolved oxygen fell to 10 - 20 per cent range as the river became warmer and slower flowing during the spring and early summer of 2016. At these levels this part of the river will not be able to maintain a broad ecology. The RMI data support this finding, with very low average scores, of between 1 and 3, in the middle reaches around Minet and Cranford.

9.3 Upper Duke of Northumberland's River

Generally the impact of the Upper DNR River is considered to be beneficial on the Crane. The RMI data, showing an average score of around 7. This indicates an ecologically healthy system (relative to the Crane catchment) and the river is also known to be a source of coarse fish for the Crane. The one major concern is the amount of phosphate entering the Crane system via the Upper Duke's, doubling the phosphate load in this part of the river. The phosphate loading has also increased in 2015 compared to 2014.

9.4 Lower Reaches of the Crane above the Lower DNR

The ecosystem generally improves with distance downstream from the upper DNR confluence to Kneller Gardens, where the Lower Duke of Northumberland's River leaves the main Crane. The nutrient loads in the river start to reduce above Donkey Wood, before the confluence with the Upper Duke's, and this is indicative of a healthier plant ecosystem and more oxygen rich environment. The nutrient removal process continues below the Upper Duke's confluence and appears to increase in effectiveness.

This part of the river has had more active management in recent years, to allow light into the river and to construct improved low flow and marginal habitats. As a result there is large scale growth of in-river vegetation and this may be both the beneficiary and contributory cause of nutrient removal. RMI data reflect this, with average scores of 8 to 9 in the lower monitoring sites.

9.5 Lower Reaches below the Lower DNR River

This part of the River Crane, below Meadway Weir, has been heavily impacted by river engineering in the 1920's and 1930's. It has not been investigated in any detail by this project due to difficulties in access. There are no monitoring sites, although 26 surface water outfalls have been assessed in terms of their impact during the Outfall safari.

The lower Duke of Northumberland's River is also outside the scope of this project. It is an artificial channel built in the 1530's and with a relatively high environmental value at present. There is little or no surface water drainage input to this channel.

9.6 Chronic Pollution Sources

Chronic sources of pollution are considered to be largely due to misconnections, although the Outfall Safari identified several other sources of chronic background pollution. There are major sources of chronic pollution in the culverted uppermost reaches of the catchment and these impact upon the whole river downstream.

The evidence from Crane Park, in the lower catchment around site 11 and site 12, indicates that the SWOP programme can reduce and remove the major part of these sources of pollution in one to two years. The local programme in Crane Park has the potential to reduce the total loading of phosphate and ammonia in the lower reaches of the river by 15 and 40 per cent. It has though yet to be shown whether (a) these reductions are long term; or (b) they can be replicated in the culverted upper reaches, where local people are not direct beneficiaries of a healthier river.

9.7 Peak Pollution Sources

There is good evidence for peak sources of ammonia and phosphate and reduced levels of dissolved oxygen impacting all parts of the river (and particularly the upper reaches), from both the Citizen Crane data and the real time monitoring. There are a number of likely and possible sources of this pollution. These are listed below and supported by data from the EA Source Apportionment GIS model (SAGIS), found in Appendix E.

- A build-up of sewage solids sludge in the system, such as that witnessed in Headstone Gardens, which is then flushed out periodically. The build-up of sewage solids is likely connected to misconnections or crossovers in the sewer system. There is good evidence that these build-ups occur and, though they might be expected to be flushed in response to rainfall events, there may be other factors that lead to their occasional disturbance. Where surface water catchments are primarily fed by urban drainage systems, during dry weather there can also be a build-up of anoxic water, which is not always linked to misconnections or crossovers. During first flush events, anoxic water can have an impact on dissolved oxygen levels, in extreme cases leading to fish mortality.
- Combined sewer overflows. There are understood to be three CSO's in the catchment and sewage pumping stations with emergency overflows are also present in the catchment. Neither have been investigated under this project, The Crane waterbody summary housed on the EA catchment explorer database provides further data on sources of pollution as well as the classifications under WFD and reasons for failure:
- http://environment.data.gov.uk/catchment-planning/WaterBody/GB106039023030
- Cross connections, other sewer system issues such as scaling of foul sewers resulting in decreased capacity, and the illegal disposal of waste water. There are links between the surface and sewerage system that may respond to either heavy rainfall events or sewer blockages for example. The importance of these features in the Crane is not known

- Other sources – such as for example the unusual sewage pollution source identified at the M4 outfall by the outfall safari and currently being investigated by the Environment Agency – said to be a private sewage source.

Further information is needed to understand the sources and potential impacts of these peak inputs. There are also likely to be other peak (largely inorganic) pollution sources related to rainfall events, such as road run-off and the flushing of gully pots for example. These have not been investigated in this project.

9.8 Sewage Treatment Works

There are no sewage works with outfalls that discharge directly into the Crane catchment. However the system is impacted significantly by the sewage works inputs to the River Colne. There is a major input of phosphate to the system from these sources, via the Upper DNR, which more than doubles the phosphate loading into the river at this point.

9.9 Geomorphology and River Shading

The nature and ecological value of the river system is also greatly affected by its geomorphology and how it is managed. There is clear evidence that the middle reaches of the river are adversely affected by river engineering, leading to straight and over-deep sections prone to silting. These and other sections are also affected by shading, which reduces the light input to the river and affects its floral ecology, leading to the system tending towards benthic algae rather than macrophytes. This in turn may be a factor in the major diurnal variations in dissolved oxygen, leading to poor conditions for river invertebrates at night.

The lower reaches (along with some of the middle and upper reaches) appear to be benefitting from improved river geomorphology, instituted by river restoration schemes and associated reductions in shading. This has resulted in a better functioning ecosystem, with extensive macrophyte growth in the summer, which may also be actively removing both ammonia and phosphate from the river.

In Summary

The River Crane is a complex urban river system subject to many controls and impacts.

The Citizen Crane project has developed a provisional model of the key controls on the water quality and associated river ecology. This model is subject to change and improvement and would benefit from more information and assessment.

The model can be used to help direct further investigations and investment priorities. An assessment of potential future plans and opportunities is set out in Section 10 below and these will be reviewed by the project steering group, Citizen Crane teams and other interested parties in the coming months.

10.0 RECOMMENDATIONS

This section sets out potential next steps for the project, and the wider Crane Valley Partnership, under various headings to answer these fundamental questions:

- How might the findings to date be applied?
- What kind and level of monitoring might be undertaken in the future?
- How will professionals be engaged in the process?
- How will the public be engaged in the process?

The final part of this section outlines the approach to delivering upon these.

10.1 Use and Development of the Findings

1. **Prioritise the upper catchment for chronic pollution reduction**. All other things being equal, resources would be best applied to reducing and removing the sources of chronic pollution in the upper reaches of both tributaries
2. **Improve the character of the middle catchment**. There is considerable work required to improve the nature and appearance of the middle reaches of the river, much of which is either hidden behind private properties, or within the public domain but obscured by vegetation
3. **Target key outfalls in the SWOP.** The Outfall Safari has helped to prioritise the key polluting outfalls for the SWOP. It would be beneficial to apply the citizen science findings to the SWOP programme prioritisation works undertaken by Thames Water as part of AMP 6 and AMP 7 planning
4. **Pin down the sources of ammonia spikes**. These are sufficiently large and frequent to merit further attention
5. **Develop a better understanding of the diurnal dissolved oxygen variations.** The project has identified, and suggested possible causes for, the diurnal variations in dissolved oxygen recorded in the spring of 2016. Further collection and analysis of stress data at the worst sites will help support targeted interventions.
6. **Promote schemes to improve the ecosystem**. These schemes might include river restoration schemes and marginal habitat development; the improved management of shading; and SuDS schemes to intercept outfalls and create more marginal habitat – maybe after they have been through the SWOP. Any interventions must be planned with long-term maintenance in mind and based on the most recent understanding of effective pollution mitigation.
7. **Investigate the Phosphate Loadings from the Colne.** It has been surprising to discover the extent of the phosphate load coming into the catchment from the Colne via the Upper Duke's River. There is value in better understanding the phosphate treatment processes in the Colne sewage works and flagging up the impact of continued phosphate loads on the River Crane.

10.2 Ongoing Monitoring

1. The monthly monitoring systems, as well as the means for undertaking the data analysis, are now in place and therefore there is a much reduced marginal cost in continuing with them.
2. The funding is in place to continue with the monthly data collection of all parameters until April 2017. There is therefore an opportunity to compare the findings from monthly data collection again after a third year of data collection. RMI funding is in place until April 2019.
3. Whilst the monthly RMI sampling will continue for two further years, there is as yet no funding for supporting, with the associated laboratory analysis, of water quality sampling beyond April 2017. There may be a case for (a) continued monthly sampling (at the same time as the RMI); or (b) reducing this to quarterly sampling, so as to provide a continued basic tracking of the catchment nutrient characteristics at reduced cost, with the possibility of increasing to monthly sampling at some time in the future.
4. Further use of real time monitoring may help to understand the main controls on water quality across the catchment. Heathrow Airport Ltd hold several years of data and full access to these data sets may be of significant help. It may also be useful to deploy further sondes to gather information from different parts of the catchment.
5. Citizen Science teams may adopt and track SWOP outfalls in their area. The local monitoring and reporting of the progress of the SWOP has been helpful in the lower Crane and may be adopted elsewhere, subject to the enthusiasm and capacity of local teams.
6. Further outfall safaris may be of value in due course to follow up this investigation and see how the conditions have changed over time. A gap of say three to four years may be appropriate and to align the survey with the AMP schedule – with the next survey being earlier in the season before the vegetation is too developed.
7. This project has not considered the impact of inorganic sources such as road run-off, although the project team has seen the work done in other catchments such as the Wandle. One option is to use the site teams to investigate the likely scale of road run-off issues in the Crane catchment, adapting approaches trialled elsewhere.

10.3 Professional Engagement

1. Continued meetings and/or links with the steering group. The Steering Group is the key interface between the citizen scientists and the statutory organisations implementing works on the ground. It is therefore essential that these links are maintained for as long as the project continues to function.
2. Engagement with other forums (for example CVP, CPiL, CaBA etc). These forums are a source of ideas and approaches for the Citizen Crane project – and there is also considerable satisfaction from seeing approaches developed in the Crane adapted and used in other catchments.
3. There have been good contacts developed with the university sector and others through this project. Ideas and information sharing will continue through these networks.

10.4 Public Engagement

1. Two short videos have been commissioned – one specifically for the Citizen Crane project and another with a wider London citizen science brief. These are designed to raise the profile of the project and stimulate interest from the public and others.
2. A proposal is in early development to create an artwork around an outfall and its drainage catchment, with the intention of raising public awareness about how their property and street are linked to the river. This project would be led by a separate arts based environmental team and would link to the Citizen Crane project.
3. There would be ongoing public engagement through the regular monitoring, leaflets, social media and other day to day means.

10.5 Proposed Approach

1. The third year of monitoring will continue until April 2017
2. Ideas and opportunities for further work will be discussed with the steering group and at the Citizen Crane forum in November 2016
3. A proposal will be developed for Spring 2017 and potential funders identified
4. Other projects, such as the arts and outfalls project, SuDS and river restoration opportunities for example, will be developed by other groups – potentially with linkages to the Citizen Crane project.

References

The Conservation Volunteers, 2014. *Volunteering impacts*

UKTAG, 2014. *River Assessment Method Benthic Invertebrate Fauna*

Appendices

Appendix A – Tabulated TW Raw data (Separate File)
Appendix B – Phosphate and ammonia loading & concentration graphs by monitoring site (separate file)
Appendix C – RMI data by monitoring site (separate file)
Appendix D – Worst offending outfalls from Osaf survey (separate file)
Appendix E – SAGIS model (separate file)