Citizen Crane

Year 4 Progress Report

Executive Summary

This report sets out the findings of the fourth year of investigation under the Citizen Crane project. The main findings are as follows:

1. The project continues to provide valuable information about the river ecosystem
2. In broad terms the river system continues to perform as per Years 1 to 3
3. The volunteer teams continue to support the project in good numbers – though more work is needed to ensure this continues over the next two years
4. The focus of the TW SWOP has shifted to the upper reaches of the catchment where major misconnection issues have been identified. In addition, LB Harrow has invested considerable resources to improving the ecological value of these reaches
5. This report includes the period to April 2018. Major improvements to the upper reaches have started after this period and early data for the last few months (to September 2018) indicate that the upstream water quality is starting to improve
6. The Citizen Crane project will also invest further in monitoring and assessing the changes in the upper reaches over the next two years
7. The middle reaches of the river system continue to be adversely affected by poor geomorphological conditions – the river being overwide and/or shaded. Major works are required, in concert with the local authorities and other interested parties, for these issues to be resolved
8. The lower catchment continues to exhibit the best water quality and ecological value. This part of the river has benefitted from large scale habitat improvements as well as the being the early focus of TW's AMP 6 SWOP programme
9. The lower catchment also benefits from flow from the Colne via the Upper DNR. Flow records indicate this has reduced considerably year on year. Lower flows risk compromising the value of the lower part of the river system
10. The project has identified a large number of pollution issues – and through working with partners has seen these resolved (or with solutions in prospect)
11. Thames Water has confirmed it will be launching the UK's first urban "smarter catchment" project on the River Crane in April 2020. The Citizen Crane project will work closely with TW over the next two years to support this programme of work so as to deliver significant improvements to the river ecosystem
12. The project has developed a detailed conceptual model of the river ecosystem alongside mass balances for AN and P. These will be reviewed and developed in the lead up to April 2020 and will provide a baseline understanding of the system for use in the smarter catchments project
13. The first "Outfall Safari" was carried out as part of Citizen Crane in 2016. The results of this safari have been followed up and led to pollution reductions across the catchment. The Outfall Safari concept is now being applied to other rivers across London. A further outfall safari is planned for the River Crane in early 2020 in advance of the smarter catchments project
14. This project has a focus on nutrients and organic pollution (specifically P and AN). However, the project has also supported partners across London to develop an improved understanding of the impact of road run-off (including hydrocarbons and heavy metal loadings) on catchments such as the Crane
15. The project has engaged with the general public and other partners around misconnections and other river pollution issues. Around 4000 project leaflets have been given out by the volunteer teams over the last four years. The project is currently working with TW to lobby local authorities and persuade the EHO teams to providing effective support to the misconnection issue
16. An overall project strategy has been developed and agreed for the next two years to April 2020

CITIZEN CRANE PROJECT

YEAR FOUR PROGRESS REPORT

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Abbreviations used:

AMP: Asset Management Plan

AN: Ammoniacal Nitrogen (NH_3-N) - *used as a measure of organic pollution e.g. related to wastewater*

CPiL: Catchment Partnership in London

CVP: Crane Valley Partnership

EA: Environment Agency

EHO: Environmental Health Office

FORCE: Friends of the River Crane Environment

P: Phosphate. *P is the chemical symbol for 'phosphorus'. For the purposes of this report we will be examining phosphate, the fraction of phosphorus that is inorganic, soluble and reactive and therefore bioavailable. P will be used to denote 'phosphate' in the text unless otherwise noted*

RMI: Riverfly Monitoring Initiative

SWOP: Surface Water Outfall Programme

TW: Thames Water

WFD: Water Framework Directive

ZSL: Zoological Society of London

Acknowledgements:

All of the Citizen Scientists who after four years of hard work continue to work towards a cleaner River Crane.

Steering Group members and their colleagues from Thames Water, The Environment Agency and Crane Valley Partnership. Special thanks to Ilse Steyl for her support since the start.

Other partners and volunteers for their engagement and interest.

1. Introduction

The Citizen Crane project is a major citizen science initiative on the River Crane. The project commenced with a Feasibility Study in 2013 and the main project work started in May 2014. This document sets out the findings of year four of the Citizen Crane project, from April 2017 to March 2018. It is the fourth in a series of annual reports recording the cumulative findings over the project. This report provides an update on the findings of the Year Three report and needs to be read in conjunction with other reports for a full understanding of the project findings. All the project reports can be viewed, along with the base data, at:

http://www.cranevalley.org.uk/projects/citizen-crane.html

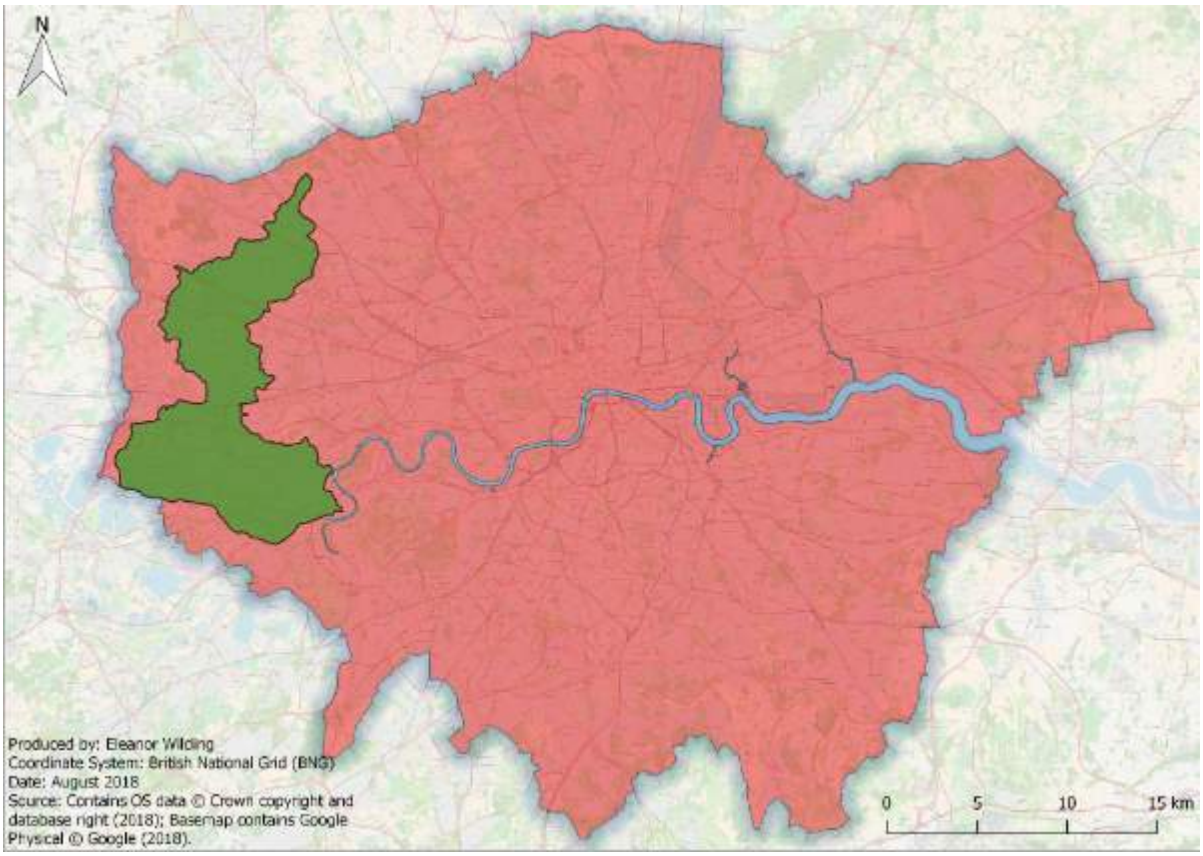


Fig. 1 Location of the Crane Catchment

2. Project Overview

The River Crane is a small urban tributary of the River Thames, running through five boroughs in west London, and covering a total area of 120 sq. km. The Crane Valley Partnership (CVP) was formed in 2005 and includes 26 partners with objectives to protect and enhance the value of the River Crane and its tributaries.

A major pollution incident in 2011 decimated the ecological value of the middle and lower Crane, killing around 10,000 fish and leaving only a few aquatic snails surviving. The Citizen Crane project was devised by CVP members in response to this incident, with the intention of investigating the basic condition of the river, identifying and quantifying pollution risks and sources, and working with key partners including The Environment Agency and Thames Water to reduce these risks and sources.

The project management team comprises Frog Environmental (a small private consultancy), Zoological Society of London (ZSL – a major conservation charity) and Friends of the River Crane Environment (FORCE – a small local charity). This team is supported by a network of volunteer groups and individuals – with around 60 individuals trained during the four years - operating 12 monitoring sites. A project steering group, comprising CVP alongside The Environment Agency (EA) and Thames Water (TW), meets every quarter.

The 12 monitoring sites have been set up at regular intervals (every 3 to 4 km) throughout the river system, each with a team of volunteers. The project operates by monthly monitoring at eleven of these sites for:

- invertebrates, using the River Monitoring Initiative (RMI) methodology
- water samples, analysed in TW's UKAS accredited laboratory for ammoniacal nitrogen (AN) and phosphate (P) concentrations
- flow measurement (river section alongside depth and velocity measurement) – used to calculate loadings from concentration data.

A further RMI measurement is taken at a 12th site.

These data provide the basic inputs for the Citizen Crane project, the scope of which after four years includes:

1. Engagement with TW and their Environmental Protection Team, investigating and resolving misconnections
2. Delivery of the UK's first Outfall Safari in 2016, using citizen scientists to visit and evaluate the condition of all 230 surface water outfalls across the catchment
3. Identification and monitoring of pollution incidents, in support of the EA and other stakeholders
4. Engagement with Universities and other researchers to use and develop upon the data sets
5. Development of a conceptual model of the chemical and ecological nature of the river system, including a mass balance of AN and P for the river
6. Preliminary investigation of the impact of road run-off on the river system
7. Preliminary assessment of the impacts of river improvement measures
8. Engagement with local stakeholders, the general public and the wider world about the project and its findings. This includes support to the extension of the project approach to other catchments within London and elsewhere
9. Supporting TW in the development of the UK's first urban "smarter catchment" initiative on the River Crane – due to start in earnest in 2020.

This report provides an update on all these project elements.

3. Project support

The following project support elements have been delivered over the last year:

- Overhaul of all the site gauging stations – including new cross section lines at all sites and the installation of new gauging boards (several times at some sites). The upkeep and maintenance of these stations requires a significant time input from the project team
- Training provided for new volunteers. ZSL provide training across London for potential recruits on the Crane and other rivers. Around 60 River Crane volunteers have gone through this training programme to date
- Private Facebook page set up for information sharing with volunteers and other interested parties
- Overhaul of the data management system – and initial sharing of the raw data sets with the volunteers (from summer 2018)
- Third annual forum held in November 2017 (with a fourth forum planned for October 2018)
- Two volunteers' social events organised for summer 2018.

The project continues to seek means of better encouraging and supporting volunteers and would welcome suggestions from all interested parties.

4. Water Quality

Background

The purpose of taking water samples is to:

- Create a detailed and reliable baseline of water quality across the catchment
- Track changes to water quality over time
- Track the impact of interventions and remedial works; e.g. SWOP and new SuDS schemes
- Identify pollution 'hotspots' and inform the prioritisation of resources for interventions across the catchment.

The water quality data consist of monthly concentration and loadings data for ammoniacal nitrogen (AN) and phosphate (P) for each monitoring site. These two parameters are measured as they are considered to provide the best assessment of organic and nutrient pollution in the river.

Flow rates are recorded at each site using a standard gauging board and flow velocity measurement system along with a pre-measured cross section. Flows are then used to calculate pollution loadings from the concentration data.

Between May 2014 and March 2018, a total of 474 samples have been collected by citizen scientists and analysed in Thames Water's laboratories as follows:

- Year 1: 108
- Year 2: 122
- Year 3: 124
- Year 4: 120

Samples are collected from each of the eleven monitoring sites along with an occasional twelfth sample from an outfall or other site of particular interest or concern (identified as Site 5 in the raw data).

The data have been reviewed and quality checked. Any data of concern have been either removed or flagged as unreliable. Full data sets were not always available due to the following reasons:

- Volunteers unavailable
- Issues with sample bottles (not available or leaking en route)
- River too deep to undertake RMI (and therefore not visited)
- Concerns about data reliability
- Loss of water level gauging boards (such that loadings cannot be calculated).

However, given the project is entirely reliant on volunteers, the overall return of reliable data (at around 90 per cent of potential data points) is considered to be very satisfactory. It is also very encouraging to note that this return has remained constant over the last three years of the project.

Water Quality Concentration Data

The following maps provide a summary of water quality data collected at sampling points across the catchment for the first 4 years of Citizen Crane project.

Data are presented as median concentration and loading values at each site for each of the four years, measured from April to March (e.g. median 2017 = Year 4 = April 2017 to March 2018). Median data are used as these reduce the impact of individual outlier data points.

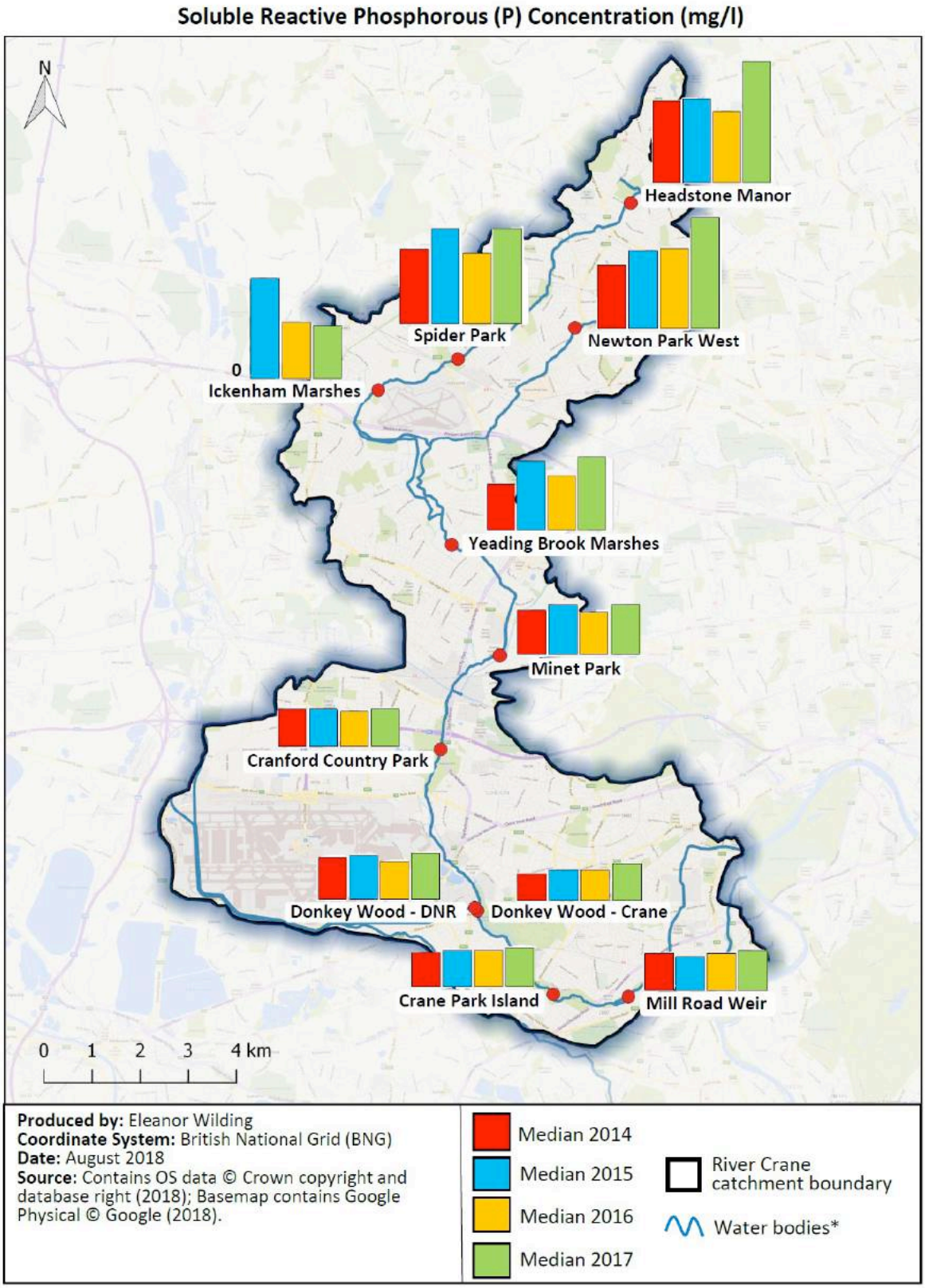


Fig 2. Median phosphate concentrations across the catchment for years 1 - 4.

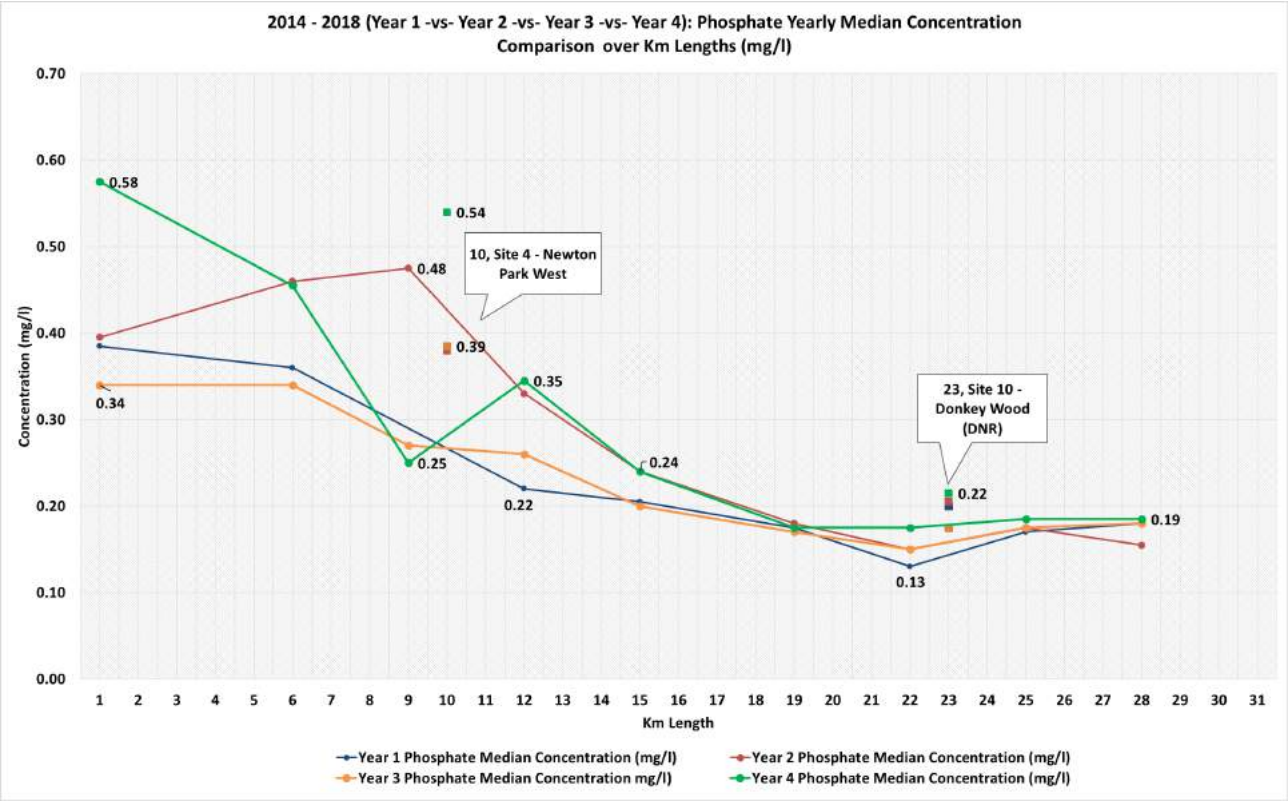


Fig 3. Median Phosphate Concentration over km lengths for years 1 - 4.

Initial conclusions drawn from these data are as follows:

- Overall the pattern of P concentrations across the catchment has remained reasonably consistent over the four years
- The highest concentration of P is consistently recorded in the two upper tributaries of the catchment, with concentration generally reducing with distance downstream
- Both upper tributaries have also seen an increase in the concentration of phosphate over time, particularly in year 4. The median at Headstone Manor increased dramatically between Y3 and Y4 whilst Newton Park has seen a concentration increase for every year of the project. It should be noted that these data largely pre-date the major shift in efforts to the upper reaches of the catchment by the Thames Water Environmental Protection Team, starting in early 2018.
- Whilst most sites in the middle catchment showed an improvement between Y2 & Y3, a deterioration back to near the Year 2 conditions is recorded in Y4 across all sites in these reaches
- The inflow from the upper DNR (sourced from the River Colne to the west) has previously been recognised as providing a higher concentration of P into the River Crane. A major source of this high P concentration is believed to be sewage treatment works (such as Blackbird STW) in the upper reaches of the Colne catchment
- Generally, the P concentrations have remained consistent throughout the four-year period for the two sites below the confluence of the upper DNR and Crane.

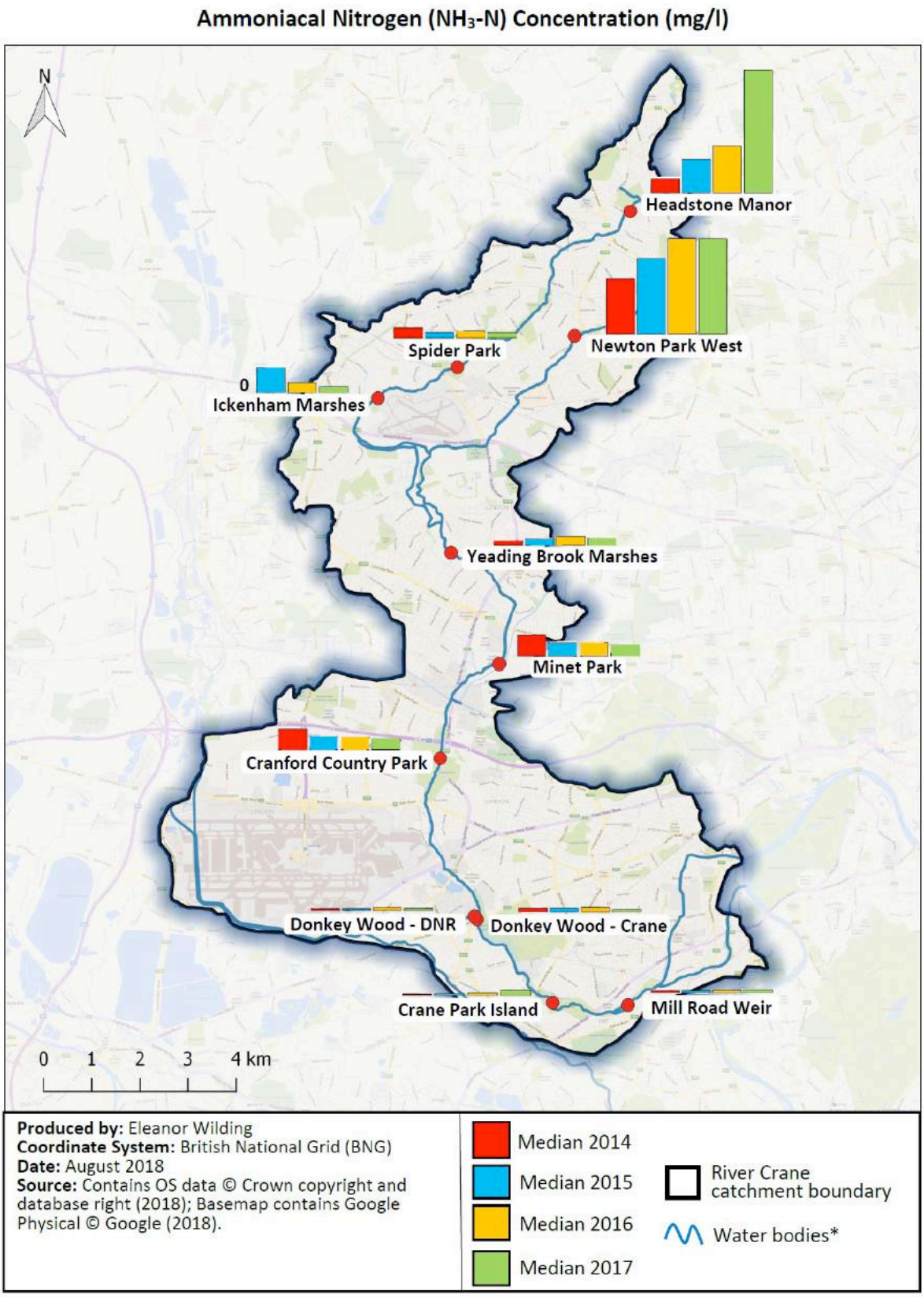


Fig 4. Median AN concentration across the catchment for years 1 - 4.

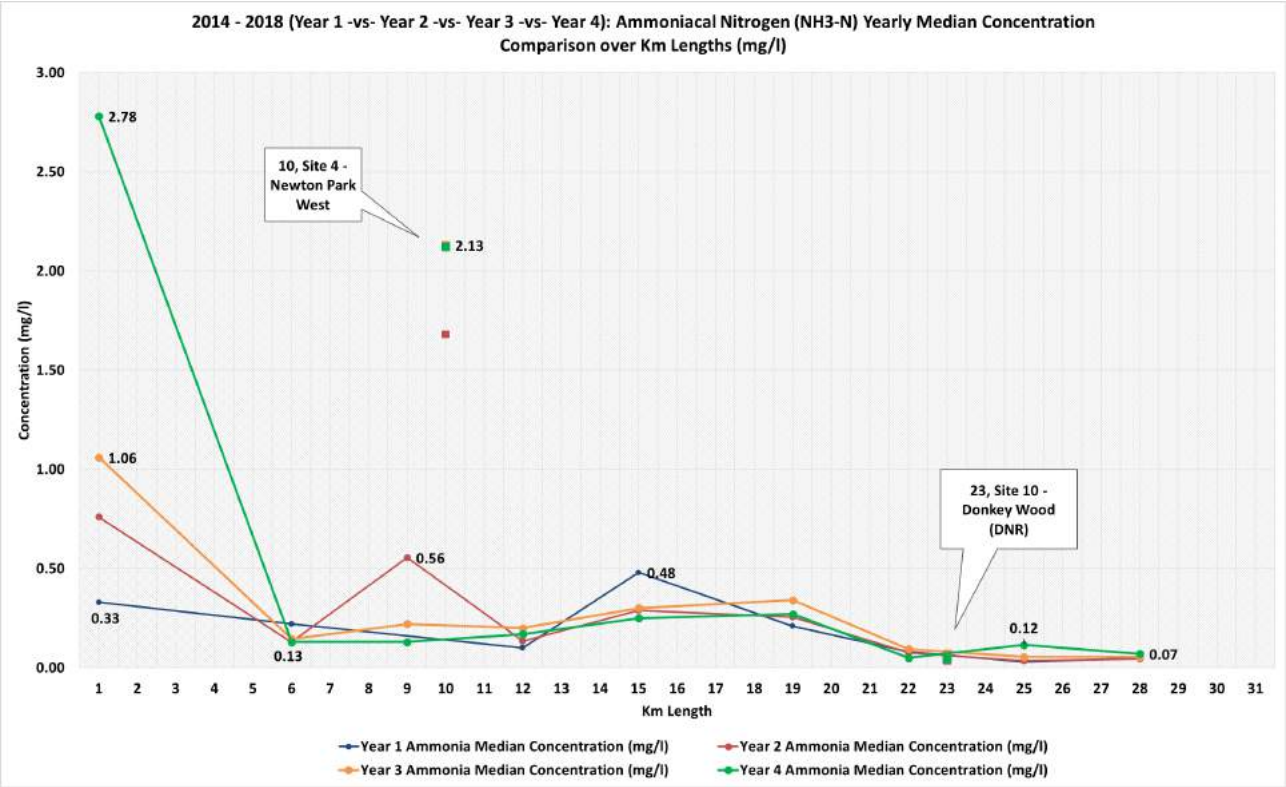


Fig 5. Median Ammoniacal Nitrogen Concentration over km lengths for years 1 - 4.

Initial conclusions drawn from these data are as follows:

- The median concentration data for each site have remained broadly consistent between years 1 and 4
- One clear exception to this has been Headstone Manor, where concentrations have increased year on year – and with a major increase in year 4
- The concentration data show major variations up and down the catchment – with large and consistent reductions in concentration between Headstone Manor and Spider Park for example. This may reflect the relative volatility of AN, combined with conditions conducive to removing it within the intervening four-kilometre reach
- Concentrations remain quite high in the middle reaches of the river
- Concentrations reduce considerably in the lower reaches of the river – though Year 4 does record increases in the lower two sites compared to previous years – sufficient alone to classify the river as poor to moderate through these reaches.

Overall conclusions are drawn at the end of this section where these findings are considered in the light of the overall data set.

Flow Data

Flow estimates are made at each site every month using a flow gauging section and measurements of flow velocity and water depth. These data are used to calculate the loadings of P and AN at each site and thereby gain an insight into how the loadings change along the river corridor.

The method used for gauging flow in the Citizen Crane project has been developed with the support of the Environment Agency, who also provided training for volunteers. It should be noted that the accuracy of results from flow gauging can be impeded by the following:

- Robustness of gauging boards at flow monitoring station. Damage to gauging boards can arise from debris during flood flows, tampering by members of public, fly tipping and general wear. This can directly lead to missing or compromised flow data.
- Seasonal issues such as aquatic weed growth. This can result in the river flow becoming funnelled into a tighter channel at the gauging station and the transect data becoming compromised. This may result in an artificially high flow rate being recorded by the volunteer
- Debris (natural or fly tipped) reducing the even distribution of flow through the gauging station and compromising the accuracy of the transect
- Shifting sediments/gravels following high flow conditions may lead to the gauging station transect being changed
- Access can be impeded to the gauging stations from terrestrial plant growth. Plants have also been known to obscure gauging markers
- Occasionally flood flows can prohibit access or even submerge a gauging station. In these circumstances accurate measurements cannot be recorded.

Water quality returns for the Citizen Crane project run at a respectable 90%, whilst flow data, which is used to calculate loading runs at a more modest 65%. Some of the issues cited above come into play when considering the validity of flow data and the loading data it produces.

Table 1: An overview of different issues encountered at each gauging station

Monitoring Site	Board Issues	Access issues	Aquatic weed growth	Storm damage	New material deposits/debris in channel
1				X	
2		X	X	X	
3			X		
	X				X
6			X	X	X
7	X	X		X	X
8	X	X		X	
9	X			X	
10	X			X	
11					
12					X

It should be noted that even Environment Agency flow monitoring stations encounter problems such as debris, which sometimes reduces confidence in the official flow record.

In 2017 there was a major re-calibration exercise undertaken for the gauging stations, with new sections created for each site and new boards installed on many of them. One of the conclusions from this exercise has been that re-calibration is required more frequently than undertaken in the past and these gauging stations require more regular maintenance and upkeep to maintain their accuracy.

Where flow data has been compromised due to a combination of the aforementioned issues, flow data has been excluded for the purpose of calculating loading.

Where there is a data return of less than 50%, or where there is a known issue impacting the confidence in flow data, these data have also been excluded from calculations.

The decision to exclude certain data sets should not be viewed as a comment on the dedication of the Citizen Scientists involved with the Citizen Crane project. The factors affecting the usability of data are often beyond the control of volunteers.

Benchmarking to EA flow data

An official EA gauging station is in place at Cranford Park, downstream of site 8 (Crane at Cranford Park, ref: 39057)

Mean flow data (expressed in cumecs) from the official gauging station are compared with mean flow return data from Citizen Crane data in the table below.

Table 2. Mean annual data from Site 8 Cranford Park Citizen Crane and EA gauging station at Cranford Park

Project year	Citizen Crane annual mean	EA gauging station mean
Year 1 (2014-15)	0.533	0.543
Year 2 (2015-16)	0.490	0.663
Year 3 (2016-17)	0.445	0.502
Year 4 (2017-18)	0.100	0.548

Year 4 data from site 8 was severely compromised due to a combination of access issues and gauging station damage. Citizen Crane data for site 8 has therefore been excluded from the loading calculations and replaced with the EA gauge data from this adjacent site.

Asides from Year 4, the EA record and the Citizen Crane record are comparable, with year 2 showing the highest variance.

Whilst flows in the upper and middle reaches are broadly comparable over the 4 years of the project, the 4 sites that are used for monitoring flow in the lower reaches all show a reduction over the project duration. All sites noted in table 6 below have an over 90% return rate on flow data and a relatively high level of confidence.

Table 3. Annual median cumec record for lower catchment gauging stations

Site reference	Year 1 median cumec	Year 2 median cumec	Year 3 median cumec	Year 4 median cumec
Site 9 Donkey Wood (Crane above DNR)	0.55	0.35	0.28	0.29
Site 10 Donkey Wood (upper DNR)	0.53	0.46	0.29	0.20
Site 11 Crane Park island (below confluence)	1.15	0.76	089	0.60
Site 12 Mill Road (furthest site downstream)	0.90	0.83	0.82	0.61

The year on year reductions in median annual flows along the middle and lower reaches of the river over the last four years is a clear feature of these data. Year 4 medians are recorded as between 40 to 60% lower than year 1 medians across the board. This characteristic has only just been formally identified by the project team and has yet to be properly assessed. Annual rainfall data for the four years from the gauging station at Heathrow are as follows:

- Year 1: 663 mm
- Year 2: 652 mm
- Year 3: 476 mm
- Year 4: 674 mm

These data do not immediately provide any explanation for the flow reductions recorded. Note that Year 4 was slightly above the long term average of 600mm for west London and the period ends in April 2018, before the start of the dry and hot summer.

A part of the explanation at least may be provided by the reduced inflows from the upper DNR, recorded as dropping to less than half the initial flow by Year 4. It is known that there are no controls on the inflow to this channel from the River Colne, and a process of steady silting and reduced maintenance may account for this reduction.

The project team will continue to investigate the potential causes of this feature of the data set.

Loading Data

Loadings are calculated by combining the water quality concentration data with the flow data. Loadings data provide an insight into the bulk amounts of P and AN in the river system at any time and place. These bulk amounts are a function of the inputs and the outputs from the system at any particular time. Figures 6 to 10 below set out the median annual loading data for P and AN over the four years of the project along with initial conclusions from an analysis of these data.

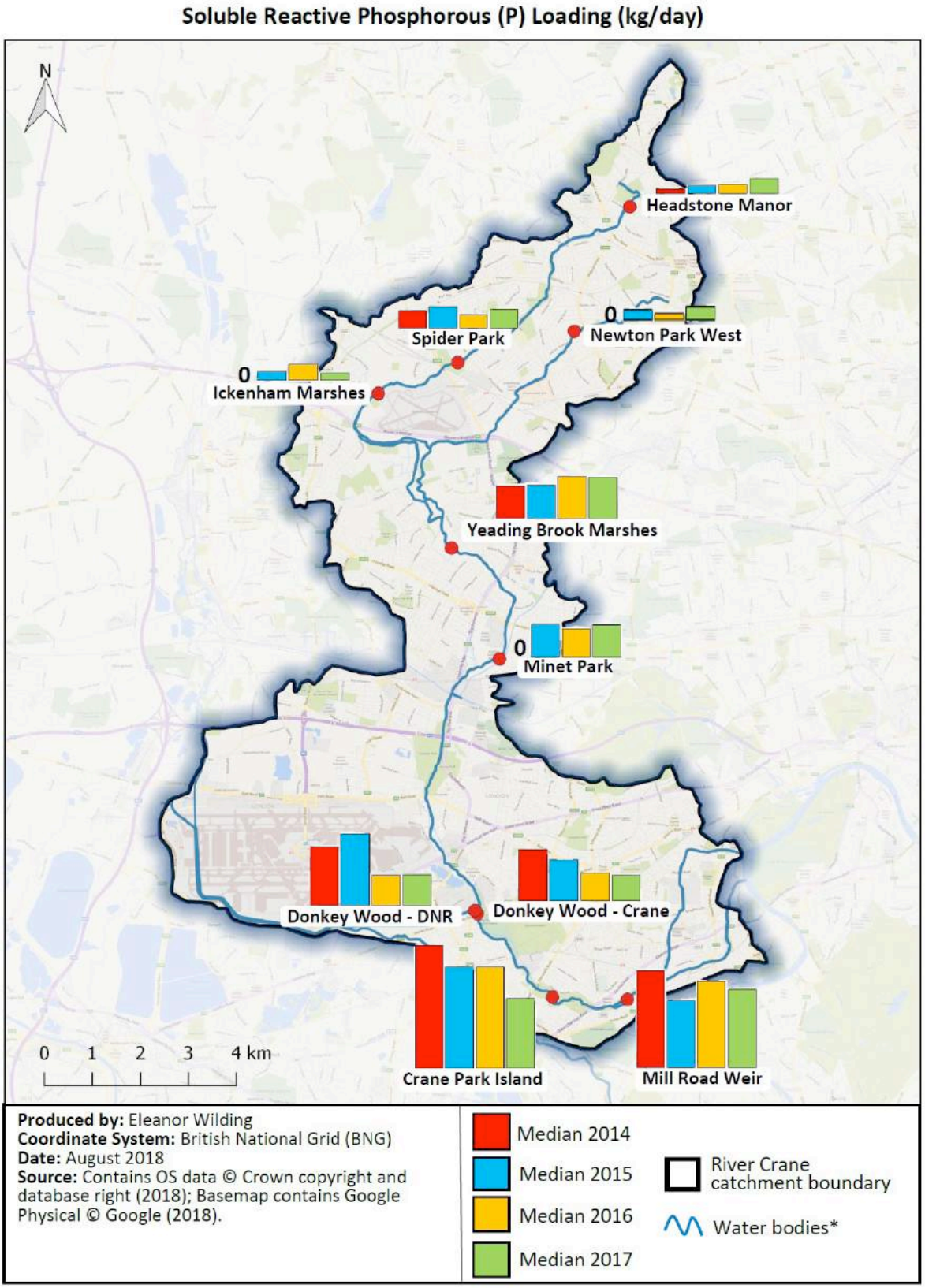


Fig 6. Median phosphate loading across the catchment for years 1 - 4.

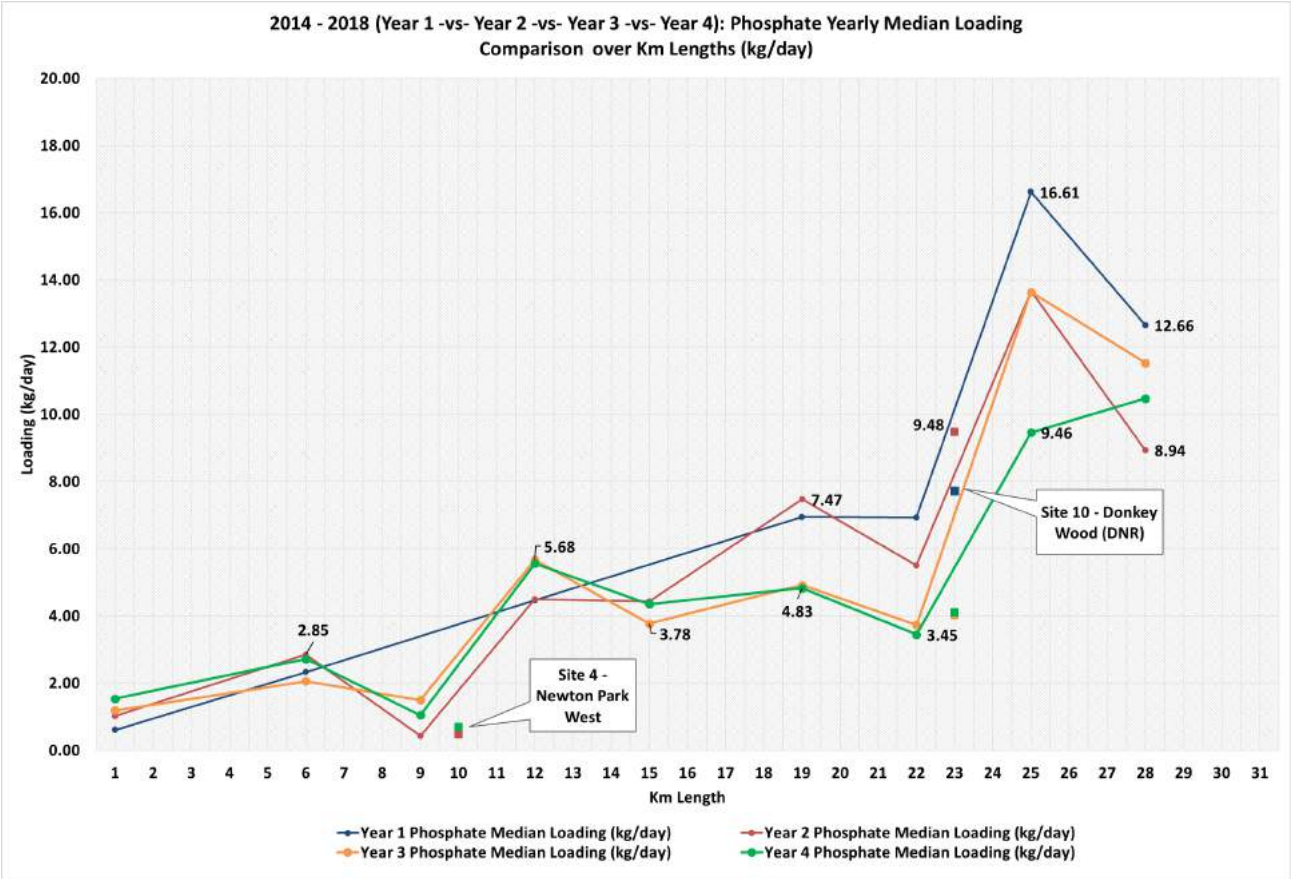


Fig 7. Median Phosphate Loading over km lengths for years 1 -4

Initial conclusions drawn from these data are as follows:

- The overall pattern of loadings is reasonably consistent across the catchment and between the four years
- There is a general increase in the P loading in Year 4 for both the upper tributaries
- Loadings in the middle reaches have remained broadly consistent over the four years
- Loadings in the lower reaches, including the upper DNR and the Crane downstream of this point, have shown a general decrease in Years 3 and/or 4.

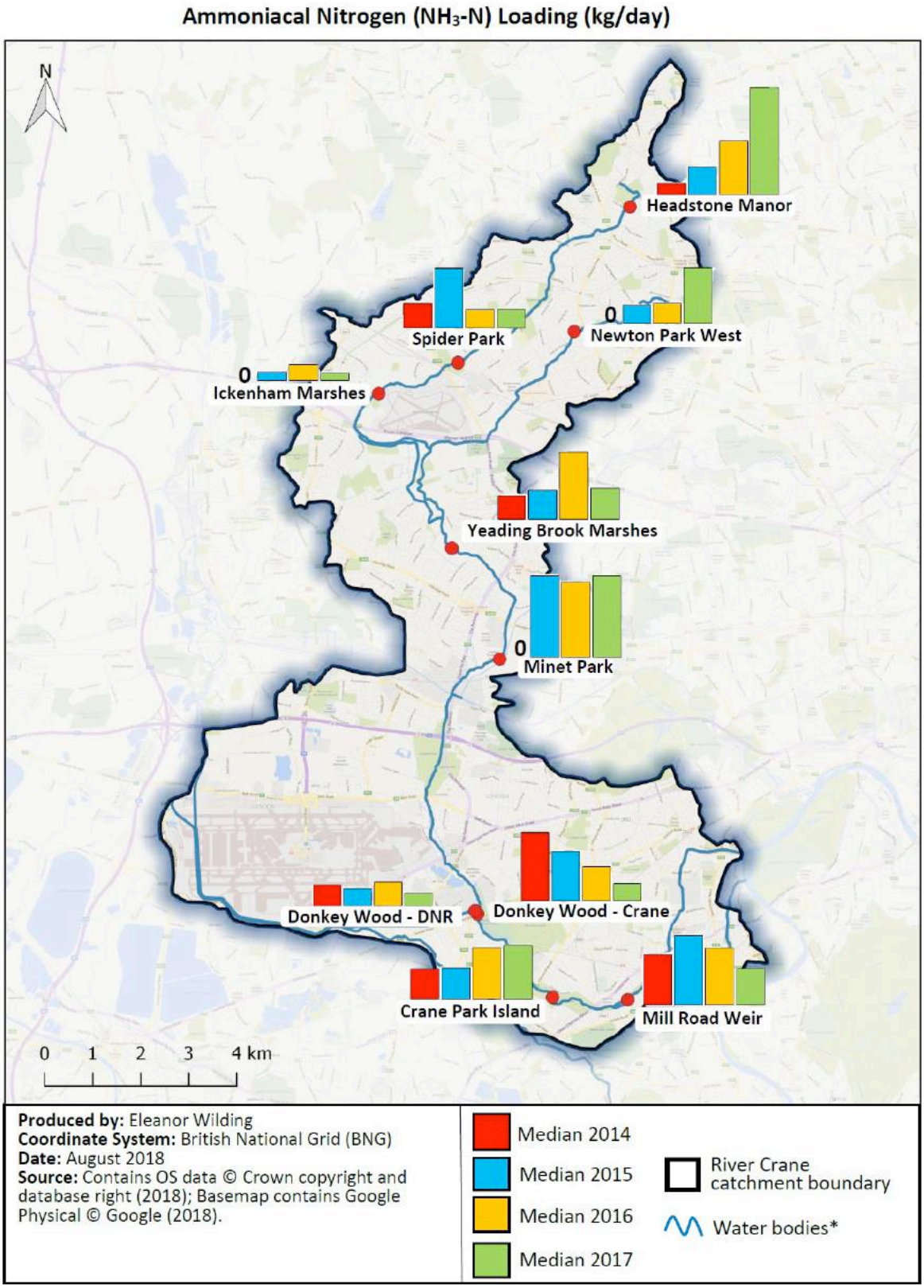


Fig 8. Median AN loading across the catchment for years 1 - 4

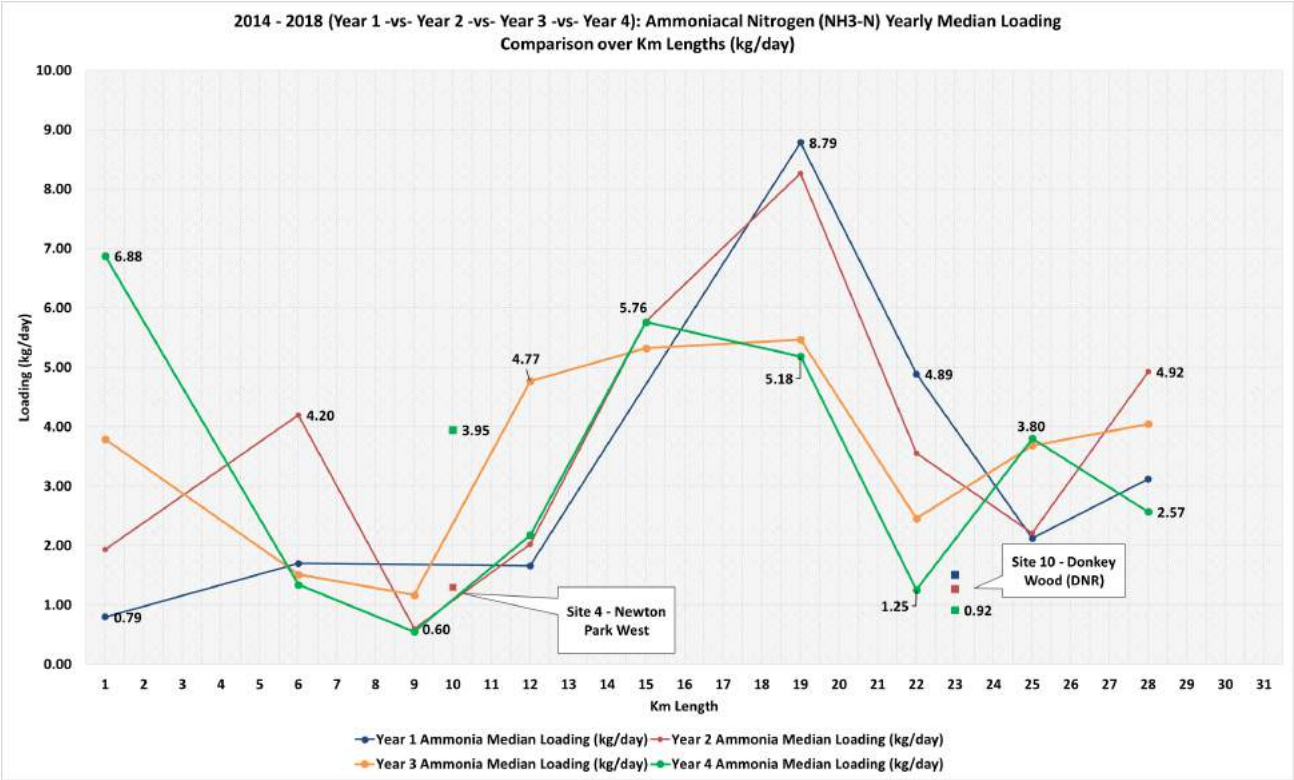


Fig 9. Median Ammoniacal Nitrogen loading over km lengths for years 1 - 4

Initial conclusions drawn from these data are as follows:

- The overall pattern of loadings is broadly consistent across the catchment and between the four years
- There is a major increase in AN in Year 4 for both the upper tributaries
- Loadings in the middle reaches have remained broadly consistent over the four years
- Loadings in the lower reaches, including the upper DNR and the Crane downstream, show a significant overall decrease in Year 4. Note that, for the first time, the total AN loading at Headstone Manor is higher than it is at the base of the catchment.

Further consideration of these data in the context of the wider data set is set out in the key findings section below.

Key Findings

Each of the key findings are set out and then considered in turn below

1. Poor Water Quality at the Top of the Catchment

This condition has been identified in previous reports. The effect has become more pronounced over the four years of monitoring and Year 4 showed significantly the highest concentrations and loadings to date at both Newton Park and Headstone Manor.

Two key things happened in the last year as follows:

- Thames Water switched its Surface Water Outfall Programme (SWOP) to the upper reaches of the catchment in response to the Citizen Crane findings over previous years. This programme started in earnest too late to affect the data presented here. However, major misconnections have been found in recent months, including entire blocks of flats and school buildings, and

many domestic properties. Water quality samples from recent months indicate that this work is benefitting the conditions in the upper catchment

- A significant pollution incident was identified at the Headstone Manor site by Citizen Crane volunteers in January 2018. This was subsequently traced to a nearby new housing development which was found to be entirely misconnected into the surface water drainage system. This problem alone may account for some or all of the very high P and AN data from the Headstone site. The issue was subsequently resolved by the developer – in co-ordination with Thames Water and LB Harrow.

There are further prospects for improvement in the upper reaches of the catchment. In summer 2018 a major wetland system was inaugurated at the Newton Park site and further environmental enhancements are planned at Headstone Manor in the coming months and years. The Citizen Crane project has received additional funding which will be used over the next 18 months to investigate the conditions in the upper catchment, and the effects of these improvement measures, in more detail.

2. Conditions in the middle reaches remaining largely unchanged

There is little evidence of any significant changes, for better or worse, in the middle reaches of the river. This indicates that the SWOP programme, which has been quite active over the last two years in this area, has not been effective in driving any significant beneficial changes to the overall water quality in these reaches.

3. Conditions in the lower reaches remain the best in the catchment and on some measures are showing further improvement

Parts of the lower catchment meet the equivalent of good status for at least parts of the year and the overall loadings of AN in particular appear to be reducing in the lower parts of the catchment – and are actually lower in absolute terms than they are higher in the catchment. This may partly reflect the benefits of the longer-term implementation of the SWOP in this part of the river. However, it may also be at least partly a result of an improved river ecosystem, following large scale improvements to marginal vegetation in the lower reaches. It is suggested that these improvements may have increased the self-cleaning capacity of the river system.

4. River flows in the lower reaches of the catchment show evidence of year on year reduction

This findings has only recently been identified and is not yet fully explained. It would appear that at least part of the explanation may lie in year on year reductions in the inflow from the upper DNR. Given that this inflow is generally recognised as being a sweetening flow for the lower Crane then this reduction may be having a significant negative impact upon the ecosystem of the lower catchment.

These findings feed into the evolving conceptual model for the river system that is discussed further in section 6 below.

It should be noted that there is considerable potential for further and more detailed analysis of the data sets and the development of these findings, including such factors as the examination of seasonal variations for example. This work will be undertaken subject to the availability of additional resources.

5. River Monitoring Initiative (RMI)

RMI Approach

A full description of the RMI methodology is available in the Citizen Crane Year Two report. The primary purpose of the RMI is to allow for the detection of pollution issues and gathering of evidence by trained volunteers to supply to the Environment Agency (EA) if further investigation is required. Trigger levels were originally set in discussion with EA staff in Year One of the project and represent levels at which a pollution incident was considered to have occurred.

The most recent example of a pollution event picked up by the breach of trigger levels was recorded in January, February and March 2018, when trigger level breaches and significant signs of pollution were reported to the Environment Agency from Donkey Wood (Crane), Crane Park Island and Mill Road sites in the lower reaches of the catchment (see also section 6 below).

Between May 2014 and May 2018, a total of 307 RMI assessments have been taken at the 12 sites out of a possible total of 396 samples. Gaps in sampling assessments have been caused by factors such as the unavailability of volunteers, or heavy rain in the catchment causing unsafe river conditions, and in the case of Newton Park the inaccessibility of the site during the construction of new wetland areas in 2018.

RMI results

Mean RMI scores at each site for each of the four years are set out in Figure 10 below. As with the water quality data these run from April to March, such that Year 4 runs from April 2017 to March 2018. This plot also shows the trigger level set for each site.

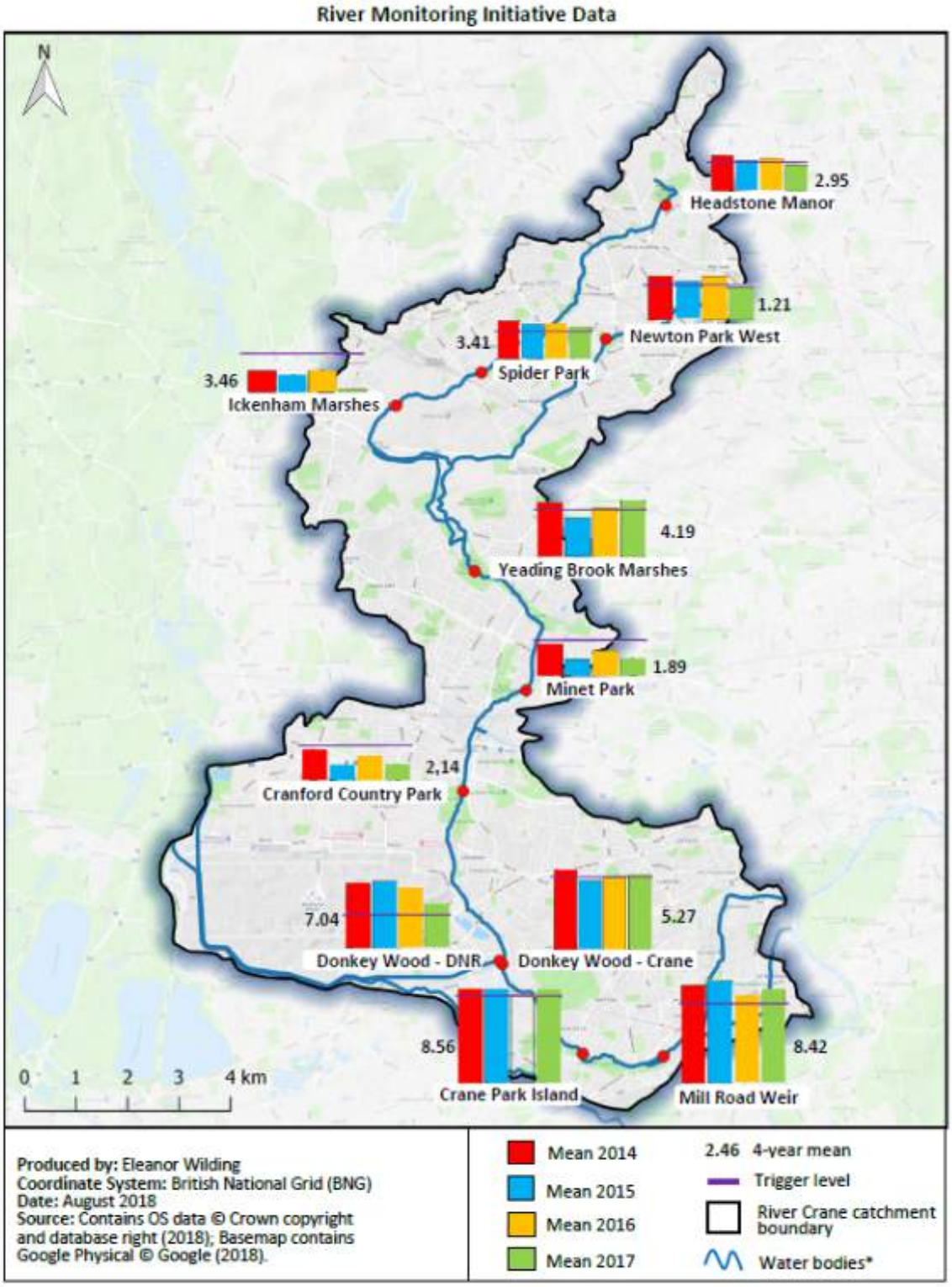


Fig 10. Mean annual RMI scores for each monitoring site

The RMI invertebrate groups recorded at least once at each site over the four-year period of the project are shown in Table 3 below

Table 4:

	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

Table 4 below shows the 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 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 5: WHPT Index values for the taxa used in the RMI method

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

Discussion

Over 900 volunteer hours have been spent RMI sampling the river during the four years of the Citizen Crane Project. Considerable value has been derived from the significantly increased frequency of monitoring by trained volunteers who, after four years with the project have honed their identification skills, and the improved synergy with the Environment Agency (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 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 Whalley, Hawkes, Paisley, Trigg (WHPT) use the differing tolerances of invertebrate families. Invertebrates with a lower score are more pollution-tolerant, and can also be tolerant of poorer habitat quality and siltation. Whereas, those with higher scores have a lower tolerance for these factors and are often absent in degraded or polluted habitats.

When reviewing RMI data 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 can only be taken as an indicative guide to ecological quality at each sample site.

RMI scores continue to be low in the upper catchment, particularly at Headstone Manor and Newton Park. This is unsurprising given the poor water quality recorded at these two sites.

Minet Country Park and Cranford Park in the middle reaches, consistently score below trigger levels agreed with the EA. Volunteers at Minet Country Park report that 'about 50% of the time there is an unhealthy smell from the river, and sometimes a sheen or it is slightly milky'. The site is also becoming progressively more shaded which may have an impact on the invertebrate community. The site at Cranford Park is both over-shaded and over-wide – resulting in a heavy sediment load and poor geomorphological character.

At these low scoring sites the normal trigger level procedure built into the RMI system, of reporting breaches to the Environment Agencies National Incident Reporting system, is no longer being implemented. Volunteers have reluctantly accepted the chronic nature of the problems and that water quality and geomorphological improvements are dependent on the ongoing long-term works programmes by others.

The two sites downstream of the confluence with the Duke of Northumberland's River (Crane Park Island and Mill Road Weir) show significantly higher RMI scores than those above.

The number of RMI invertebrate groups found in samples from each site, shown in Table 4 above, unsurprisingly follows a similar pattern to the mean scores by site. Invertebrate communities in the upper part of the catchment are compromised, and 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. Gammaridae are the only group to be found at all sites and stonefly (Plecoptera) are found at none.

Greater invertebrate diversity, including the only records of true mayfly (Ephemeridae), has been recorded in samples downstream of the upper DNR. A total of three individual flat bodied mayfly specimens have been recorded from three separate sites: Yeading Brook Meadows, Crane Park Island and Mill Road Weir. 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.

Conclusions

The main conclusions, considering the RMI data alongside the water quality data in section 4 above, are as follows:

1. The RMI scores at the top of the catchment are poor, and this is not surprising given the water quality data. In fact, given the water quality, there is some encouragement in the scores, and the presence of several different species in these upper reaches (though not at Newton Park). This may be due to the basic geomorphology being reasonably good in the upper reaches and therefore the potential for ecological recovery, as and when water quality improves, may be good.

2. The RMI scores reduce in the middle reaches around Minet and Cranford Park, even as the water quality generally improves. There may be particular reasons at Minet, due to local poor quality as reported by the site volunteer team. At Cranford Park the reasons may be more due to poor geomorphology, with an overwide, silted and shaded channel resulting in poor conditions for invertebrates. There is a major Lottery Funded project starting in Cranford this year and this may

provide an opportunity to enhance the river through the site. In general the geomorphology of the middle reaches of the river is sub-optimal with considerable potential for improvement.

3. The RMI score for the Upper Duke of Northumberland's River (DNR) in Donkey Wood is higher than for the adjacent River Crane upstream of the confluence. This has been the case throughout the four-year monitoring period and is despite relatively high P concentrations in the Upper DNR. The inflow from the DNR is sourced from the River Colne catchment to the west, the river including high quality chalk groundwater from the Chilterns as well as P loadings from treated sewage effluent from works such as Blackbirds STW.

   RMI scores in the Upper DNR have tailed off though, starting in year 3 and continuing through year 4. Our data do not indicate any significant shift in the river water quality and the effects on the RMI may be due more to the reduced flows along this channel, as noted in section 4 above. Reduced flows along the Upper DNR are a more general concern for the health of the lower Crane, due to the value of the inputs as a sweetening flow, and also during low flow periods when low and zero flows can be an issue in the river below the Lower DNR offtake in Twickenham. The flow date from the Citizen Crane project have been the only systematic record of flows in this channel and have been reported to the EA and Heathrow Airport Ltd, who are investigating the issue further.

4. RMI scores in the lower reaches of the river at Crane Park Island and Mill Road are consistently the highest in the catchment, at above 8. These are the only sites where 7 RMI species have been found (the next highest being 5) and the only sites where mayflies are found. The water quality data indicate these sites also exhibit the lowest concentrations of P and AN in the catchment, though P concentrations are comparable with several sites upstream.

   Of most importance may be the relatively high value of the ecosystem in this part of the river. There are a variety of river habitats including riffles and deeper glides and pools, combined with extensive marginal and in-river vegetation. These conditions, in combination with the better water quality, are resulting in an enhanced RMI score, indicative of an improved overall ecosystem.

   A considerable amount of work has been undertaken over recent years to improve the river geomorphology in the lower reaches. Toe boarding has been removed and new river deflectors and marginal habitat areas have been created and planted. These improvements have been put to a major test over the last nine months, first by a major pollution event in January to March 2018 (see section 6 below) followed by a very warm and dry summer. To date (September 2018) the RMI scores for these reaches have proven remarkably resilient to these impacts, first recovering from the pollution event and then being sustained through the summer low flow period.

5. The trigger levels at various sites, including Cranford, Ickenham and Minet, do not adequately reflect the current poor ecological value of the river in these locations. The project team will discuss with volunteers, the EA and others, whether these would benefit from being revised.

6. Wider Investigations and Observations

Overview

This section sets out the findings during Year 4 from a range of wider investigations and observations, either directly implemented by the Citizen Crane project team or linked to the project in some way. These include:

1. Outfall safari: first implemented on the Crane catchment in the summer of 2016 and reported in the Year Three report
2. Road Run-off: recognised as a chronic pollution source in urban catchments such as the Crane
3. Long term outfall surveys: started by the Citizen Crane team during Year Two
4. Pollution reporting: listing pollution events identified and/or monitored during Year Four
5. SWOP: feedback from Thames Water on their misconnections programme
6. Improvement works: overview of key ecosystem improvements implemented or proposed for the catchment
7. Mass balance for P and AN: first developed in the Year Three report
8. Overall conceptual model for the river system: first developed in the Year Two report and updated in the Year Three report.

Updates on each of these are set out below.

Outfall Safari

In the summer of 2016 the Citizen Crane project carried out an "Outfall Safari" for the catchment. An App was developed to record the condition of surface water outfalls using the Thames Water reporting methodology as the starting point. This was then used by volunteer teams, who visited and reported on a total of 230 outfalls and around 35km of river corridor across the catchment over a six week relatively low flow period. The River Crane Outfall Safari is believed to have been the first volunteer led outfall monitoring project implemented in the UK – unless anyone knows differently.

The main findings of the Outfall Safari were reported in the Year 3 report. The main developments since this time are as follows:

- All of the outfalls reported as being polluted have been investigated by Thames Water and/or the Environment Agency
- Several discrete pollution issues were identified through this process and have since been rectified
- The Thames Water SWOP was reviewed in the light of the findings of the Safari and those outfalls identified as polluted were either added to the SWOP or put onto a separate priority list for early investigation
- The Safari highlighted the grossly polluted upstream culverted channels above Newton Park and Headstone Manor. These findings encouraged TW to switch SWOP resources to focus on these areas, subsequently identifying major misconnection problems. The benefits of this SWOP programme are starting to be seen in improved water quality results from Newton Park and Headstone Manor in recent months
- The Outfall Safari approach has been recognised by Thames Water and the wider water sector as being of high value in identifying problems as well as engaging local interested communities in monitoring and improving their river environment
- The Outfall Safari approach has been refined and developed by ZSL – along with an updated App. Over the last two years ZSL and TW have implemented Outfall Safaris in a number of river systems across London, covering a total of around 200km of river corridor. TW and ZSL are currently finalising an agreement to undertake 120km per year of Outfall Safari across London over the next seven years

- The intention is to repeat the River Crane Outfall Safari in early 2020, at the start of the Crane Smarter Catchment programme.

In short this has been a very successful programme, reaping considerable benefits for the understanding of the Crane catchment and enabling more targeted responses to specific pollution issues. The approach has subsequently been developed and is being applied to many other sites across the TW region – and is also receiving interest from other parts of the UK.

Road Run-off

Road run-off is recognised as being a significant source of chronic pollution in urban areas including the Crane catchment. Urban drainage catchments generally include run-off from the public highway as well as from properties. Road runoff is a particular problem following extended dry periods, when road particulates and oils build up and are then flushed into the river system alongside the detritus held in the drainage system. The Citizen Crane project does not have a specific remit to investigate road run-off. However, there have been various initiatives linked to the project and these are identified below:

- An MSc Thesis by a student from Royal Holloway College in 2016 investigated the road run-off from the M4 with support from the Citizen Crane project. This project collected samples from the road run-off and the sediment downstream of the outfalls and identified major pollution issues coming from the M4. The work findings were included in an EA proposal for improvement works to these outfalls and this is currently with Highways England for consideration as part of a major national programme of works.
- An MSc Thesis by a student from Cranfield University in 2016 investigated the condition of river sediments throughout the catchment including extensive sampling supported by the Citizen Crane project. The report identified major and chronic pollution problems in the upper, middle and lower reaches, much of which may be linked to road run-off. The condition of the river sediment may prove to be a significant control and influence on the potential for water quality and wider ecosystem improvements to the river corridor.
- The Citizen Crane project team has engaged in the development of a "Position Statement on Road Run-off Pollution" which is being developed through the Catchment Partnerships in London (CPiL) group**.** The purpose of this document is to set out the London wide issues around road run-off and identify funding and policy developments appropriate to investigate and best improve the impacts. It is due for completion in late 2018.
- ZSL are also engaging with Thames 21 to develop a funded programme of road run-off initiatives – which will include Citizen Science interventions. The Citizen Crane project will continue to liaise and monitor this initiative and identify potential joint working opportunities.
- Frog Environmental has recently (September 2018) appointed a 3 year funded PhD post at Swansea University. The scope will incorporate site investigation works – likely to include the Crane catchment.

The ways in which road run-off interacts with the wider river ecosystem will continue to be an area of interest and investigation for the Citizen Crane project, subject to the development of these and other programmes of work.

Surface Water Outfall Programme

The Surface Water Outfall Programme (SWOP) is managed by Thames Water Environmental Protection Team (EPT) and has become a main practical means of identifying and rectifying chronic pollution problems identified through the Citizen Crane project. EPT works to improve the status of the region's watercourses in partnership with the Environment Agency and other stakeholders. The EPT focus on tracing and removing pollution from drainage misconnections to surface water sewers, which are designed to convey untreated rainwater directly into a watercourse.

The SWOP started in Asset Management Plan (AMP) Period 5, from April 2010 to March 2015 and was increased substantially in AMP 6 (to March 2020). TW's representative on the Citizen Crane steering group also helps to manage the SWOP and provides a very helpful interface with it.

The latest data on the progress of the SWOP in the Crane catchment is set out in Table 5 below

Table 6. Thames Water Summary of SWOP: AMP6 to date (September 2018)

	Outfalls	**Misconnected Properties Identified**	**Misconnected Appliances**	**Misconnected Properties Rectified**	**Outstanding Misconnected Properties**
AMP6 SWOP – Live projects	12	180	342	139	41
AMP6 SWOP – Signed off by the EA	34	369	1104	355	14
Waiting List	9				
Total		549	1446	494	55

* Thames Water has also developed a new team called 'Network Resolution Team' to investigate outfalls identified through Outfall Safaris and other river walks. The aim of the team is to address polluted outfalls as soon as possible and determine whether a catchment is suffering from few misconnections and/or other pollution sources or whether the pollution is caused by widespread misconnections, which would require a strategic long-term investigations through SWOP. This team is active in the Crane – though the project does not yet have any data on the misconnections work completed.

The following points are made in relation to these data:

- The SWOP is considered to be having a major beneficial impact upon the river system. Calculations presented in the Year 3 report indicated that the SWOP may remove in the order of 0.1 to 0.2 kg/day of P and AN from the river system for each significantly improved outfall
- A mass balance for the river system was presented in the Year 3 report and has been reviewed and summarised at the end of this section. This needs further external review and development to provide a definitive assessment of the beneficial impact of the SWOP on the river
- The impact of the SWOP has increased in Year 4 (and in recent months to September 2018). This is due in part to the change in focus to the upper reaches of the catchment where major misconnections have been found, including housing blocks and school buildings, each equivalent to many individual properties
- One factor which is not yet well understood is the rate at which new misconnections are being added into the system. Without these data it is not possible to assess the net benefit of the SWOP – or whether the SWOP is even keeping pace with the new misconnections. Through this project the Citizen Crane is requesting TW and/or others undertake further research into this issue
- Around 90 per cent of property owners appear to be rectifying their misconnection issues within a short period of receiving notice from TW. However, if property owners fail to rectify their misconnections, cases are being handed over to the Environmental Health Office (EHO) of the relevant Local Authority for enforcement. TW identified two councils to the Citizen Crane project team that had stopped responding to TW requests for support. These were approached by the project team and one has subsequently renewed active involvement whilst the other has stated it is not able to for financial reasons. This matter is still being assessed by TW and the project team remains available to engage with the EHO and the wider council as appropriate

TW's proposals for AMP 7 have recently been published. These set out an enhanced SWOP for the five years starting in April 2020 and it is anticipated this will include further measures on the River Crane.

In addition, the River Crane has been identified as being the UK's first urban "Smarter Catchment", in a major project included in the AMP7 proposals. It is anticipated that this project will link closely with the Citizen Crane programme.

Long Term Outfall Surveys

The Citizen Crane project started to monitor the condition of selected outfalls in the lower reaches of the catchment in April 2016. The surveys started with all the outfalls within Crane Park and continued monthly until the present day – although the scope was subsequently reduced to include five key outfalls only, each of which were included in the SWOP.

Assessments are made of the condition of each outfall every month, including the flow, the amount of sewage fungus present on the apron and any evidence (visual or olefactory) of pollution. The main findings are noted below:

- In each case the SWOP has improved considerably the water quality emerging from the outfall
- In each case there is some evidence of residual pollution – in some cases consistent and in others occasional
- In one case (Hospital Bridge Road) the outfall is proving very challenging to fully rectify and it remains as an active SWOP outfall over two years after it was first investigated. It is not clear whether this is due to one or two misconnections which are proving difficult to remedy – or to new misconnections being added to the drainage network.

The data set is available to TW and the project team and may prove of value as a longer-term record of the performance of outfalls that have been through the SWOP.

Other surface water outfalls are regularly identified by Citizen Crane volunteers as causing water quality problems. These are then monitored more closely by the volunteers and often investigated further by TW and/or EA staff. In a number of cases these investigations have led to the improvement of the outfall performance whilst in others the outfall remains as an active investigation by TW, either by the SWOP or the Network Resolution Team.

Pollution Events

A large number of pollution events have been identified and/or monitored over the four-year course of the Citizen Crane project. The main activities are summarised below:

1. Citizen Crane volunteers visit 12 sites along the river every month and are the eyes and ears of the project for these sites. Volunteers are encouraged to report any pollution problems identified during their site visits - to both the EA hotline 0800 807060 and the TW incident hotline on 0800 316 9800. Broader issues around water quality and the condition of the river at the site are reported to the project steering group as well as contacts in the relevant local authority. This approach has resulted in a rapid response by the EA and/or TW to a number of pollution incidents as well as actions to clear up littering and fly tipping for example through the local authority.

2. The Outfall Safari identified 47 (of 227) surface water outfalls with a pollution score of 4 or above. These were all investigated by TW and those found to be polluting were added to the SWOP or dealt with under other TW programmes. Several of these outfalls were identified as grossly polluting and were dealt with immediately by the EA pollution team.

3. The M4 outfalls at Cranford Park remain as the most polluting road run-off sources identified by the project in the catchment. Some improvements have already been achieved, under enforcement works led by the EA. The project team remain hopeful that works will be undertaken by Highways England to improve the condition of these outfalls under their national programme.

4. In January 2018 there was a major pollution issue developed in the middle and lower reaches of the River Crane linked to the use of glycol de-icer at Heathrow and leading to widespread and long lasting "sewage fungus" blooms covering the bed of the river and smothering the river bed habitat. This is similar to the incident report in the winter of 2016/17 in the Year Three report. The Citizen Crane teams monitored the situation and produced a report (shared with the EA and Heathrow Airport Ltd) that mapped the impact upon downstream RMI scores over the six-month period following the initial outbreak.

   In the summer of 2018 the project team visited the Heathrow site at the request of the environmental management team. The incident was discussed in detail and the team visited the site of the new treatment plant that is designed to manage the glycol problems at the airport in the future. This plant is due to be commissioned in winter 2018 (at a cost of around £20m) and it is hoped that this will greatly reduce the vulnerability of the middle and lower reaches of the river to pollution events like this in the future.

5. In January 2018 the project team identified a major sewage pollution issue at the Headstone Manor site and this was subsequently traced to a large new housing development local to the site, the sewerage system for which was misconnected to the surface water drainage. This pollution is believed to be at least a part cause of the major increases in P and AN recorded for the Headstone site in this report.

   The misconnection issue was resolved fairly soon after the problem had been identified and the developer subsequently made a significant ex gratia payment to the Crane Valley Partnership. These monies will be used by the Citizen Crane project to enhance the engagement with the issues in the top of the catchment over the next 18 months.

Improvement Measures

The Crane Valley Partnership and its partners have been delivering a large number of river improvement measures over the last ten years and more are planned for the next five years. A summary of the key measures is provided below:

1. A large number of river improvement schemes have been implemented across the middle and lower reaches of the catchment in the period following the major pollution incident in the river in 2011. More than 5km of river and marginal habitat improvements have been undertaken in total and it is considered that these will have had a cumulative beneficial impact on the river ecosystem. These improvements are also likely to have enhanced the capacity of the river to deal with pollutant inputs and operate as a self-cleaning system – by narrowing the river channel, introducing more vegetation, resulting in more oxygen in the system and more effective sediment scouring.

2. A major new scheme has been completed in Newton Park west in the summer of 2018. This comprises four large settlement and interception ponds that have been installed to intercept the stream flow in all but highest flow conditions. It is anticipated these will remove organic sediment from the system and allow environmental processes to improve water quality. Citizen Crane

volunteers have added a second monitoring site at Newton Park to be able to assess the condition of the outflow water from the system and assess the effectiveness of these measures.

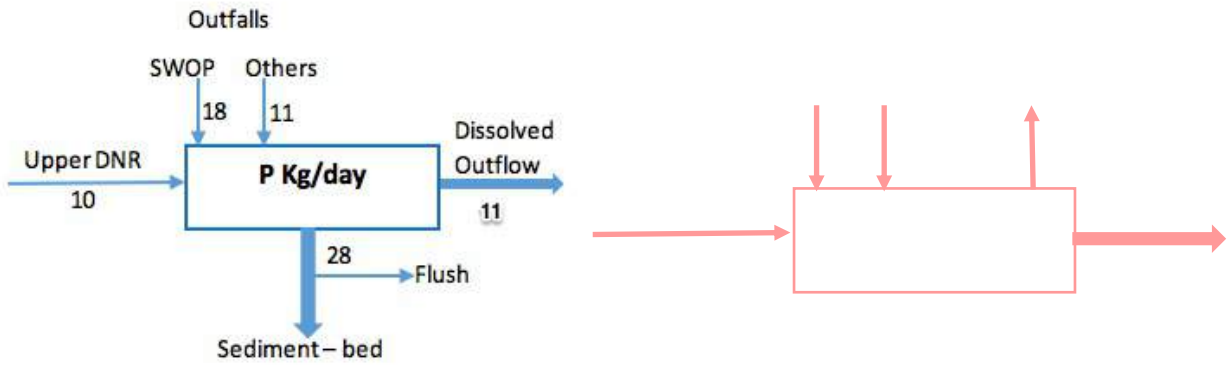
3. Further major river system improvements are scheduled at Newton Park and Headstone Manor on the two upper arms of the river over the next two years. The intention is to increase the Citizen Crane monitoring of these systems over the next 18 months to evaluate their effect on the river water quality and wider river ecosystem.

4. The Thames Water smarter catchment project starts in April 2020 and is anticipated to include further river enhancements and SUDS schemes. The Citizen Crane teams expect to be included as an active part of this project so as to provide real time monitoring and feedback to this programme and help to optimise its effectiveness.

Review of the Conceptual Model of the River System

The Citizen Crane Year Two report contained an overview of the project's understanding of the River Crane as a system. The overview split the river into upper, middle and lower reaches as well as commenting on tributaries and sources of pollution.

In the Year Three report this conceptual model was reviewed and updated. The Year Three report also presented an initial mass balance for P and AN, considering sources, sinks and outflows. A conceptual drawing of the mass balance has now been produced for this report and is presented below on Figure



SV

Fig 11. Mass Balances for P and AN (kg/day)

The works in year four of the project have not led to any major re-thinking of the conceptual model of the river, nor has the mass balance work been re-visited. It is intended that a formal review of both the conceptual model and the mass balance will be undertaken, in conjunction with the TW team, in the lead up to the Smarter Catchment programme of work over the next two years to April 2020.

Upper DNR

1.0

7. Stakeholder Engagement

Volunteers

Citizen Science volunteers continue to be the mainstay of the project, undertaking the main data collection and monitoring tasks at 12 sites across the catchment. Volunteers are also playing a key role in the logistics of the project: water quality sample collection is managed by volunteers and they are also engaged with the wider reporting of surface water outfalls and their condition.

Key points concerning volunteer engagement are as follows:

- The annual citizen crane forum provides an important opportunity to meet all the volunteers along with other key interested parties, share ideas and discuss the opportunities and priorities for the following year. The Year Three forum was held at ZSL in November 2017. Volunteers expressed a high level of support for continued monitoring at the Forum
- New volunteers continue to be recruited, with two training sessions last year
- A good level of feedback is received from volunteers on a monthly basis
- For data collection alone, more than 1600 hours of volunteer time has been logged by the end of year four. This equates to over 200 working days. It should be noted that volunteering involvement with Citizen Crane stretches beyond data collection and the total figure for volunteer hours will be much higher
- A dedicated Group Facebook page has been set up and managed to provide regular information to and by the volunteer teams
- The raw data sets have been updated and access provided to all the volunteer teams for their use and development
- A Thames 21 volunteer has been included in the steering group to provide a volunteer perspective
- A first volunteer social event was held in LB Harrow in summer 2018, linked to the opening of the new wetland site at Newton Park. A further event was held on the River Thames later in the summer.

The project team will continue to review and develop the support provided to volunteers and their role in the project.

Local Communities

The Citizen Crane teams continue to engage with local people during their monthly monitoring sessions and to hand out leaflets explaining the project and the wider issues of misconnections and river pollution. FORCE volunteers and others also hand out these leaflets at community events and talks. A further 4000 explanatory A5 leaflets were produced for the project during Year Four, updating and replacing the 4000 that have been largely distributed to date. 500 copies of a more detailed A4 technical sheet were also produced in Year Four, containing more detailed project information.

Regular messages about the project and specific project findings are put onto the FORCE Facebook and Twitter accounts: see www.force.org.uk for links. Two walks and talks have been held over the last year, introducing local people to the project. A Citizen Crane stall was provided at the Mogden Open Day in 2018 and a presentation on Citizen Crane was provided as part of the London National Park City launch event.

Thames Water

Thames Water has committed funds to support the Citizen Crane project up to April 2020. Thames Water has also committed to use of resources at their UKAS accredited lab for a corresponding period

of time. Accredited lab results, alongside appropriate collection and storage protocols, give confidence to the data and support the use of Citizen Crane data in strategic decision-making.

In addition, Thames Water are key members of the steering group and have been very supportive of the project and acted positively with developments to the SWOP and other aspects of their programme in response to project findings. TW have identified Citizen Crane as a key partner for their AMP 7 programme starting in April 2020.

The River Crane will be the UK's first urban "smarter catchment" in a pilot project scheduled for AMP7. This project is in part a response to the positive relationships developed over the Citizen Crane project. The details of how this project will operate and link to Citizen Crane will be worked up over the next two years with a start date of April 2020.

Local Authorities

Generally, the relationships with local authorities and the project are positive and there has been particularly strong engagement with LB Harrow regarding their ambitious programme of improvements in the upper reaches of the catchment. During Year Four the project contacted two local authority EHO departments that had stopped engaging with TW on the misconnections programme. One of these has re-engaged with the programme but one LA has not, citing lack of resources. The project team remain hopeful that further engagement with key contacts in TW and the LA will help to resolve this issue.

Academia

In Year Three the project helped to deliver a number of research projects and these were of value in developing the understanding of the catchment. There were no research projects delivered in Year Four. However the team remains willing to engage with academics around the use of the project data set and the catchment for related research purposes. One major potential development is the start of a PhD looking at road run-off problems, based at Swansea University and likely to engage with the project as part of the research field work.

Wider World

A paper on the outfall safari was presented at the River Restoration Centre conference in spring 2018. A poster of the wider project was also developed for this conference and is available for future conference work as required.

The project continues to engage with the Catchment Partnerships in London (CPiL) group and has contributed to CPiL position papers on misconnections and road run-off in the last two years. There are a number of initiatives across London that are using the findings of the Citizen Crane project to inform their work programmes.

Citizen Crane and the Outfall Safari were presented as a key collaborative project at the National Water Summit in May 2018.

8. Project Strategy to 2020

A project strategy to the end of the AMP6 period in April 2020 was presented to the 3rd annual Citizen Crane forum in November 2017. This project strategy has been developed in the light of the responses to the forum and other discussions since with key stakeholders and is presented below.

1. Continue monthly baseline monitoring of water chemistry, river flow and Riverfly Monitoring Initiative (RMI) sampling at 11 sites (currently 12 RMI including Roxbourne Park) – along with continued regular engagement with Thames Water, Environment Agency and Crane Valley Partnership (CVP) as part of the steering group, until April 2020.

2. Keep the data collection methodology and practicalities under regular review. A large-scale review and re-calibration of the gauging locations was completed in 2017. It is anticipated that further re-calibration works will be required in 2019.

3. Continue to support Citizen Crane teams, seek to retain the existing volunteers and to engage new volunteers by:

    a. Providing feedback through regular contact and the annual forum. An internal Facebook page was launched in 2018
    b. Offering training and development opportunities. Twice yearly RMI training is being offered through ZSL. Options for further training will be sent to volunteers as these become available
    c. Keeping volunteers up to date on the wider impact of the work they are contributing to
    d. Encouraging volunteers to interrogate the data sets – keeping a complete and up to date data set (including flow and loading data) on the CVP web-site
    e. Supporting, where possible and through the catchment partnership, initiatives developed by the volunteer groups
    f. Site visits to key schemes. Options include: Heathrow eastern balancing reservoir and associated treatment systems; interception and enhancement works in Harrow with LB Harrow and HNCF (completed in summer 2018); river restoration works in the upper and middle reaches of the river with LWT
    g. An annual social gathering for volunteers (first one in May 2018)
    h. Link with technical specialists at TW, EA, LA's, Univs, LWT and other interested parties to support the project teams as well as identify potential volunteers.

4. Develop the skills of the core group and add to the understanding of key catchment processes by undertaking further citizen science activities up to 2020. Options include:

    a. Providing new extended RMI ID sheets to all volunteer teams (ZSL to consider)
    b. Testing geomorphological improvements at specific sites to assess the impact on RMI scores and their consequent value for wider implementation (trial proposed at Site 12 for later in 2018)
    c. Engagement with key projects – using the methodology to assess the benefits from project implementation. Projects are developing around this initiative for the Headstone Manor and Newton Park schemes in collaboration with Thames 21
    d. Targeted investigation of outfalls identified as being problematic during the 2016 outfall safari – largely complete but subject to review
    e. A further outfall safari in early 2020.

5. Continue to liaise with the SWOP programme and feed relevant data to the project team for their information. Continue to monitor SWOP outfalls local to key Citizen Crane monitoring sites and report the conditions to TW. Liaise with TW, EA, local authorities and the general public to

optimise the beneficial impact of the SWOP – including engagement with EHO teams where appropriate.

One key aspect of the misconnection issue is the likely rate of new misconnections being added to the network and therefore requiring fixing in order to maintain the status quo before any improvement is delivered. TW reps were not aware of any good data on this at present – though it will be fundamental to delivering improvement through the SWOP. The project will seek further data on this and use it to refine the mass balance for the catchment.

6. Identify the principal sources of AN and P and give broad source apportionment figures in the river system, by refinement of the mass balances - including work with the EA SAGIS model, review of upper DNR flow data and wider discussion with key interested parties (including EA and TW specialists).

   Undertake further review of existing research – plus identify further research opportunities as appropriate – to evaluate the role of various in-river processes as sinks and/or removal agents for of AN and P.

   Feed these data into Thames Water's AMP 7 investment priorities in the catchment (particularly the River Crane "smarter catchment" initiative). Also feed this understanding into the Environment Agency and Catchment Partnership's developing programmes of work.

7. Identify the causes of the 'pulses' of increased AN identified by the EA real time monitoring data (and reported in Year Two). Review further real time data held by the EA and HAL for example. Note that subsequent discussions have indicated that some at least of these peaks may be false positives caused by other pollutants presenting as AN. Assess the potential impact of combined sewer overflows (CSO's) and other time limited inputs on the overall mass balance and the river ecosystem.

8. Track the changes in river condition caused by the continuing SWOP programme and other measures implemented by all parties e.g. TW system changes; river restoration projects; the provision of additional marginal vegetation etc. Use the Citizen Crane data to help optimise the implementation of these work programmes.

9. Investigate the reduced flows identified in this report. In particular consider the significant decrease in flows recorded for the inflows from the Upper DNR.

10. Collate the available data on sediment volumes and chemistry; from information held by University projects, EA, LA, LWT and other investigations.

10. Map and rank the principal road run-off impact zones and make mitigation recommendations. Note that this will require additional funding. This work may link with the proposed ZSL and Thames 21 programme currently being developed (Summer 2018)

    Work with partners to instigate remediation programmes at one (or more) priority road run off pollution sites. Note: the EA has submitted proposals to Highways England for remediation works at the M4 outfall.

    Consider how the level of maintenance, through gutter and gully pot cleaning for example, is affecting the build-up of sediment in the river system – with reference to other studies.

11. Continue to engage with other practitioners and academics in London and elsewhere to cross-fertilise ideas:

    a. Continued liaison with London based and other Universities, and support to undergraduate and post graduate projects, using the base data and collecting further relevant data as appropriate
    b. London academics and practitioners forum
    c. Other initiatives through the "Catchment Based Approach" and "Catchment Partnerships in London"
    d. National RMI initiatives
    e. Other links to be identified.

12. Target of seeing, by April 2020, significant reductions in AN and P levels and increased overall RMI scores. Delivered through a combination of measures – and largely implemented by 3rd parties (SWOP; pollution prevention, system changes; marginal vegetation; SuDS etc).

13. Citizen Crane to utilise social media to engage Citizen Scientists and the wider public. Use these tools to raise the profile of the Crane catchment, SWOP programmes and other issues of importance to delivering the targets set out above. The project team will deliver annual reports charting the progress of restoration efforts and manage an annual forum with an invited audience designed to support the delivery of these targets. The EA will produce update reports on pollution investigations across the catchment for circulation to all interested parties.

9. Summary and Conclusions

This report sets out the findings of the fourth year of investigation under the Citizen Crane project. The main findings are as follows:

1. The project continues to provide valuable information about the river ecosystem
2. In broad terms the river system continues to perform as per Years 1 to 3
3. The volunteer teams continue to support the project in good numbers – though more work is needed to ensure this continues over the next two years
4. The focus of the TW SWOP has shifted to the upper reaches of the catchment where major misconnection issues have been identified. In addition, LB Harrow has invested considerable resources, supported by HLF and others, to improving the ecological value of these reaches.
5. This report includes the period to end of March 2018. Major improvements to the upper reaches have started after this period and early data for the last few months (to September 2018) indicate that the upstream water quality is starting to improve
6. The Citizen Crane project will also invest further in monitoring and assessing the changes in the upper reaches over the next two years
7. The middle reaches of the river system continue to be adversely affected by poor geomorphological conditions – the river being overwide and/or shaded. Major works are required, in concert with the local authorities and other interested parties, for these issues to be resolved
8. The lower catchment continues to exhibit the best water quality and ecological value. This part of the river has benefitted from large scale habitat improvements as well as the being the early focus of TW's AMP 6 SWOP programme.
9. The lower catchment also benefits from the input of flows from the Colne via the Upper DNR. Flow records indicate this flow has reduced considerably year on year. This effect risks compromising the value of the lower part of the system
10. The project has identified a large number of pollution issues – and through working with partners has seen these resolved (or with solutions in prospect)
11. Thames Water has confirmed it will be launching the UK's first urban "smarter catchment" project on the River Crane in April 2020. The Citizen Crane project will work closely with TW over the next two years to support this programme of work so as to deliver significant improvements to the river ecosystem
12. The project has developed a detailed conceptual model of the river ecosystem alongside mass balances for AN and P. These will be reviewed and developed in the lead up to April 2020 and provide a baseline understanding of the system for use in the smarter catchments project
13. The first "Outfall Safari" was carried out as part of Citizen Crane in 2016. The results of this safari have been followed up and led to significant pollution reductions across the catchment. The Outfall safari concept is now being applied to other river across London. A further outfall safari is planned for the River Crane in early 2020 in advance of the smarter catchments project.
14. This project has a focus on nutrients & organic pollution (specifically P and AN). However, the project has also supported partners across London to develop an improved understanding of the impact of road run-off (including hydrocarbons and heavy metal loadings) on catchments such as the Crane.
15. The project has engaged with the general public and other partners around misconnections and other river pollution issues. Around 4000 project leaflets have been given out by the volunteer teams over the last four years. The project is currently working with TW to lobby local authorities persuade the EHO teams to providing effective support to the misconnection issue
16. An overall project strategy has been developed and agreed for the next two years to April 2020.