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'Changing behaviour, changing investment, changing operations': using citizen science to inform the management of an urban river.

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Abstract:

Significant quantities of data are being collected by citizen scientists concerning environmental challenges. Networks of volunteers can collect data on spatial and temporal scales that may be beyond the resource and logistical capacities of the governmental bodies and other organisations that monitor and protect the environment. However, citizen science may be viewed with scepticism by decision makers and excluded from decision-making because it is perceived as being of poor quality and lacking scientific credibility. This paper explores how citizen science has been used to inform the management of an urban river. It uses the example of the River Crane, a small urban river in London, U.K., to demonstrate how data gathered through a volunteer project, Citizen Crane, supported decision-making about the river. Through analysis of interviews with the project's leadership group, the paper examines how the project leadership team developed a high degree of credibility with stakeholders in the river management. This included drawing on the expertise of stakeholders to design the project and align the monitoring approaches with technical and scientific standards. Other factors of importance included open and professional communication between the Citizen Crane leadership team with regulators and businesses, and the development of shared understandings and expectations about the river's management. The leadership team drew on their professional experience to inform the design and management of the project, and to provide a conduit for data gathered by volunteer scientists to be embedded in decision-making. The paper unpicks the ways in which citizen science challenges traditional notions of expertise in environmental decision-making, and contributes to understanding how citizen science can support more legitimate and effective strategies for tackling complex socio-environmental challenges.

1. INTRODUCTION

This paper explores how Citizen Crane, a citizen science project concerning the River Crane in west London, influenced the management of the river. It demonstrates how the project's leadership team drew on their professional expertise to develop effective relationships with stakeholders in order to generate credible, high-quality data. This was used by the Environment Agency (EA) and local water company to inform specific management activities. A growing body of citizen science literature addresses the motivations of volunteer scientists (e.g. Geoghegan et al., 2016), including those participating in Citizen Crane (Dunkley, 2018). In contrast, this paper provides a novel insight into how the design and management of a citizen science project can influence environmental decision-making.

The paper is structured as follows. Section 2 overviews the literature relating to citizen science and decision-making, followed by a description of the Citizen Crane project (Section 3) and the research methods used (Section 4). The main outcomes of the project are discussed in Section 5, whilst Sections 6, 7 and 8 analyse the main themes emerging from the research. Section 9 articulates how citizen science may be embedded more widely in decision-making and identifies some ways in which this could be achieved.

2. CITIZEN SCIENCE

Large quantities of data are required to inform decision-making about complex socio-environmental challenges. This is often beyond the resource and time constraints of many government agencies, statutory bodies, and charitable and non-governmental organisations. Citizen science, a form of science in which volunteers engage in collecting, analysing and processing data, is often used to meet this need. Citizen engagement with scientific practices is not a recent phenomenon, but technological advances such as high-speed mobile data connectivity and GPS-enabled mobile devices have transformed opportunities for crowd-sourcing data (Dickinson et al., 2012). Haklay (2015) also argues that societal changes such as longer life spans, better education and increases in leisure time facilitates greater citizen engagement with scientific research. Silvertown (2009) suggests that the public-impact agenda of funding bodies and opportunities for large-scale data collection further drives interest in citizen science for scientific research.

Citizen science provides an important mechanism to enhance public participation in policy-making (Irwin, 1995). The European Commission notes that citizen engagement can better define problems of concern, generate new policy ideas, and improve the ownership of policy outcomes (European Commission, 2016). Bringing together diverse stakeholder perspectives facilitates the co-construction of policy decisions that are better adapted to local conditions, reduce implementation costs, and improve dialogue among opposing stakeholder groups (Sprain & Reinig 2017). In the UK and Europe, policy objectives explicitly advocate the use of citizen science data in decision-making (Nascimento et al., 2018). Citizen science is having a profound and wide-ranging influence on governance, particularly that concerning environmental conservation (McKinley et al., 2017; Dickinson et al., 2010). For example, citizen monitoring of farmland birds has been used as an indicator of agricultural intensification (e.g. Gregory et al., 2005) and is included in the UK's Sustainable Development Indicators (DEFRA, 2013), and the Riverfly Partnership submitted a Biodiversity Action Plan as part of the UK's response to the Convention on Biological Diversity (Ballard et al., 2017).

The potential of citizen science to inform policy is dependent on overcoming scepticism about data quality (Conrad & Daoust, 2008; Kosmala et al., 2016). Dimensions of citizen science data quality (sampling protocol, dataset completeness, precision and accuracy; Lewandowski & Specht, 2015) may be difficult for volunteers to adhere to without high levels of species identification and access to technical equipment, and when using oversimplified protocols (e.g. Buytaert et al., 2014). There are inevitable trade-offs in data quality, such as comprising completeness to increase accuracy (Lukyanenko et al., 2016). Between-volunteer variability in measurements is generally higher in citizen science datasets, although this has been contended (e.g. Aceves-Bueno et al., 2017; Specht & Lewandowski, 2018).

The practice of citizen science has disrupted the ways in which expert knowledge is used in decision making (Irwin, 1995; Evans 2008). Traditionally, the public were seen as receivers of knowledge produced by experts (the 'deficit model'; Wynne, 1991). However, the public are increasing playing a role in democratic decision-making through public participation in governance (Quick & Bryson, 2016). Whilst citizen science can play an important role in facilitating more active public engagement, Nascimento et al. (2018) argue that much of the discourse around citizen engagement positions the public as data collectors or processors, with genuinely active engagement with governance remaining rare. This reinforces how technical and scientific expertise often exists in closed professional communities, which are exclude non-experts through scientific protocols, professional codes, and positivist approaches (Ottinger, 2010; Sprain & Reinig, 2018). In contrast, non-expert knowledge is often considered to be subjective and informal, and derived from everyday experiences and serendipity (Petts & Brooks, 2006). Therefore, a key challenge for policymakers is to integrate these contrasting forms of knowledge into decision-making.

3. THE RIVER CRANE AND THE CITIZEN CRANE PROJECT

The River Crane drains a small (c. 125 km^2), heavily urbanised catchment in west London, U.K. The Crane is channelized for much of its 35 km length, in common with many urban rivers, and receives runoff from urban surfaces including from roads and London Heathrow airport[1]. The river is also affected by sewage misconnections[2] via surface water outfalls, and in combination these factors result in generally poor water quality. Public interest in the health of the river and its environs is widespread, and many organisations have an interest in the management of the river (Figure 1A)[1]. The river has also been subject to major pollution incidents, including serious sewage-discharge events in 2011 and 2013 which caused significant ecological damage and widespread loss of fish (Ambrose, 2014).

Following the 2011 event, a river restoration fund was established by the water company and partly used to establish the Citizen Crane project. This comprises two ongoing monitoring programmes: water sampling for chemical indicators of pollution and the Riverfly Monitoring Initiative (RMI) (Figure 1B). Water samples are collected by volunteers and analysed by the local water company. Volunteers also estimate discharge. The RMI is a widely used citizen science initiative used throughout the U.K. to detect pollution events. It is based on a simple scoring system by recording the presence and abundance of eight invertebrate groups (see www.riverflies.org). The RMI is a simplified version of techniques used by the EA for Water Framework Directive (WFD) monitoring (e.g. WHPT)[3]. Eleven sites[4] along the River Crane have been monitored on a monthly basis by around 40 trained volunteers since April 2014: an estimated 1600 hours of time has been volunteered for data collection alone (Citizen Crane, 2019). An additional survey of surface outfalls (the Outfall Safari) was undertaken by Citizen Crane scientists in 2016 in order to identify potential misconnections and other sources of polluted runoff.

[1] Further information about the catchment, its management and the Citizen Crane project can be found at http://www.cranevalley.org.uk/catchment/catchment-information.html.
[2] A misconnection occurs when a source of wastewater (e.g. domestic drains) is plumbed directly into surface water drains, rather than the sewer system.
[3] Whalley, Hawkes, Paisley & Trigg metrics are used by the Water Framework Directive UK Technical Advisory Group (WFD-UKTAG) as a tool to assess general degradation in rivers.
[4] For more information on the sampling sites and the data collected, an interactive map is available online at https://bit.ly/2XX9LCb. Further details of the methods used by volunteers can be found at the project website: http://www.cranevalley.org.uk/projects/citizen-crane.html.

4. METHODS

All three members of the Citizen Crane leadership group and five key stakeholders (including four in the project steering group; Figure 2) were interviewed by the author between June and August 2017 (who at the time was engaged in the project as a volunteer scientist in the project and participated in project meetings and forum events). A semi-structured approach was used to ensure the intended topics of the interview were covered (an example interview schedule is included in Supporting Information). The interviews generally lasted 1–2 hours, were recorded, and then transcribed with participant's names changed before being analysed thematically. Secondary data were used to supplement the interview data, gathered from project reports, discussions held at steering group meetings, and informal discussions during river monitoring activities. The analysis was informed by the author's engagement with Citizen Crane and primarily sought to elucidate how the Citizen Crane project led to improvements in the management of the river.

5. OUTCOMES OF THE CITIZEN CRANE PROJECT

A common theme expressed by the interviewees was that the data produced by Citizen Crane enhanced the understanding of the river and therefore enabled more effective management interventions to be undertaken. Prior to the project, the Crane was monitored by the EA in accordance with the risk-based WFD requirements; seven sites continue to be sampled 12 times a year for physico-chemical parameters. However, David pointed out that the EA had 'closely-clustered sampling sites; Citizen Crane given much better resolution, spatially' whilst Sarah thought that the EA were 'getting more – and quality – evidence' about the Crane. Ben spoke about how Citizen Crane data complimented regular EA monitoring to target interventions following a trigger score being exceeded:

> 'We were monitoring, didn't know exactly where the source [of pollution] was, RMI helped us focus down… did a river walk and now we have a water quality improvement'.

Naomi and Martin both referred to the importance of Citizen Crane data in evidencing improvement works. Data about the river chemistry and ecology, rather than just the discharge from an outfall, meant it was possible to document how remediation works were improving the river.

Citizen Crane data also complemented existing river monitoring data to better define the location of chronic pollution sources. At the catchment scale, Citizen Crane showed that pollution mainly came from the north of the catchment, whereas the water company had focussed pollution remediation works in the south. Helen explained that Citizen Crane had provided evidence for changing the water company's focus for tackling outfalls: 'moving the location of focus within the AMP[5] period…I don't think that would have happened without this project'. Linda described this change as 'really huge', directly linking Citizen Crane to the water company's change in practice: 'discussions around what we do clearly changed outfall remediations'.

There were also benefits arising from Citizen Crane at a local scale. Naomi explained that Citizen Crane had identified outfalls that the water company were unaware of, and also helped determine if remedial works had been successful: in some cases, works 'signed-off' were re-investigated based on Outfall Safari data. Ben added that the Outfall Safari found outfalls that were not the responsibility of the water company, leading to investigations with landowners. Similarly, a polluting outfall draining the M4 motorway was at a site not routinely monitored by Citizen Crane, but highlighted for remediation by Highways England. David thought this notable as, in his opinion, it was evidence that the project had enhanced awareness of the Crane more broadly.

A consistent theme in the interviews was the improved reporting of pollution incidents that had occurred since Citizen Crane began. The large number of outfalls draining into the Crane meant that pollution spills were common. Ben noted that the quality of information being received was higher than before the project, meaning that they could more effectively prioritise their responses to incident reports. He argued that the incident reports from the Crane were more evidence-based than in other catchments:

> '…other [citizen science] groups tell you of an issue, "here is a piece of litter"…where Citizen Crane differs, they get out and tell us how much they've seen…it's evidence based'.

The leadership team used the EA's incident reporting service when necessary, drawing on the collective familiarity with the river's environment to identify unusual colours, smells or fungal growths: as Sarah put it, 'it's people going to the river that know the river'.

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[5] The privatised UK water industry is regulated by the Water Services Regulation Authority (Ofwat) which sets the price of water supply to consumers at the beginning of five-year periods (Asset Management Plans; AMP), based on the water company's business plans.

A final notable outcome were the wider benefits of the citizen science work for stimulating interest among the public in their local environment. Citizen Crane was seen to be part of a growing desire in the Crane Valley to 'empower and educate' people to be active participants in their environment. James suggested it was also a potential springboard to an 'intrinsic' engagement with their local area. Linda was particularly passionate about how the project linked to broader public engagement with societal issues. Her points demonstrated a belief in how interest in a river could link to wider issues of proactive community engagement:

> '…[it is] part of a broader tranche of work that we are keen to see happen that embraces community engagement, action on the ground, social actions, health, education, a whole range of ways that communities are more proactive in looking after their spaces…proactive because they are empowered… [Citizen Crane] gives people the sense they can take a more active role in improving things for the better'.

Citizen Crane enhanced both opportunities for engaging communities in environmental issues and the environmental quality of the River Crane. The ways in which this happened are explored in the next three sections, focussing on i) the emergence and design of the project (Section 6); ii) data quality and professional remits (Section 7), and iii) effective project leadership (Section 8).

6. THE EMERGENCE AND DESIGN OF CITIZEN CRANE

The high-profile 2011 pollution incident galvanised the existing public interest in the river and provided financial and technical support for a citizen science project. Linda reflected how Friends of the River Crane Environment (FORCE; a local charity concerned with the River Crane and associated green spaces) had 'overlooked' the river, and that the 2011 pollution event provoked a switch of focus towards the river being 'intrinsic to what we [FORCE] do'. Whether or not the incident was key to launching Citizen Crane is debateable: although Sarah thought the pollution event had been an opportunity, James and Linda envisaged that a project would have evolved anyway because of the strength of local interest in the river.

The design of Citizen Crane was based on developing a positive working relationship with the EA. David explained that Linda's initial approach to the EA had been based on wanting to support the EA to manage the river more effectively, and Ben remarked on the proactive efforts of the project team to align with EA practices. He elaborated on this unique element, saying that the project team were 'wanting to really understand how we [the EA] operate and how we do things….to drive forward decision-making'. Ben explained that 'our [the EA] priorities are not all about the Crane, we have to prioritise to meet WFD objectives; the Citizen Crane group understand that'. Sarah later commented on how another river citizen science project she was familiar with lacked this engagement with the EA, and was having a markedly limited impact.

The project team used and designed appropriate protocols, which helped to establish the credibility of the project. The RMI and the Outfall Safari methods already existed and were appropriate for citizen science research in terms of the expertise and skills required to use them. To develop other aspects of the project, such as protocols for water sampling and flow gauging, a feasibility study was undertaken, using the advice and guidance of EA technical staff. Chemical analysis of water samples was done by the water company's accredited laboratory, rather than using less accurate field test kits. As Linda put it, this meant that 'as a polluter [they] cannot deny the data'. James too recognised the importance of this for how the data were viewed:

> 'Getting [the water company] to do the lab work was absolutely critical… it's the accuracy of the data, but more than that it's the legitimacy of the data'.

Early engagement with the EA and water company was a key strategy for establishing the credibility of the project (Freitag et al., 2016). Drawing on expert knowledge enabled protocols and standards to facilitate the legitimacy of the data, rather than act as a boundary to prevent its use in decision-making (Ottinger, 2010). The water company's role in analysing samples clearly played a large role in establishing Citizen Crane data as legitimate, and the leadership team's broad understanding of regulation and business practices enhanced the credibility of their project leadership (Section 8). Understanding the EA's need to prioritise remedial work also helped the steering group communicate realistic expectations of change to the volunteer teams.

7. DATA QUALITY AND PROFESSIONAL REMITS

One of the main factors influencing the success of Citizen Crane was that the dataset was thought to be of good quality. The use of protocols and standards designed with input from the EA reinforced the credibility of the data (Section 6). In addition to this, the project used ad-hoc, informal data checking processes. James referred to cross-checking discharge estimates with data from EA flow gauging stations. Helen explained how she would check for issues with data management, such as '"0s", rather than "no data"' when adding data to the project's interactive map. She added that the RMI would have been checked by Sarah who would spot anything unusual because she knew the volunteer teams and what would be an expected value for each site. Helen used her 'professional judgement and experience' when plotting data in the GIS to highlight unusual data. David and Ben explained how reviewing drafts of the annual report enabled them to improve the quality of reporting, such as technical terminology about chemical pollutants. Volunteers would record any unusual observations about their monitoring sites; Linda was keen to emphasise the importance of data quality to the volunteers:

> '[The] best way of showing the importance of data quality is showing how it is changing behaviour, changing investment, changing operations… we feed this back [to volunteers]: "you guys are changing this"'.

Although generally viewed positively, some concerns were raised about the data quality, in two main aspects: the suitability of the RMI method for a degraded urban stream (it was designed for less polluted rivers) and potentially poor temperature control of water samples (which can cause degradation of chemical compounds prior to analysis). This might have led to undetected pollution events and inaccurate chemical measurements. Sarah identified additional volunteer training as important but beyond the capacity of the project team to deliver. However, these trade-offs in data quality were not thought to significantly compromise the interpretation of the data.

A tension around data quality emerged from the EA. David and Ben viewed Citizen Crane data as high quality, and were keen advocates of the project within the EA. However, national-level teams (e.g. those doing catchment pollution modelling) were less confident in it. David questioned whether this was an issue of 'data collection or attitudes', and referred to the institutional culture of the EA: 'the "old school" say "What's the point [in citizen science]? We do it!". Ben argued that citizen science was seen as an infringement on the roles of EA staff, some of who were described as 'protective of what they do… job security comes into it'. A broader institutional picture of decreasing funding may have been important here in linking 'free' data to the threat of redundancy. Both Ben and Sarah recognised the shifting of monitoring from the EA to volunteer groups as the 'eyes and ears' of the EA on the ground. Sarah questioned the morals of this:

> '…the concern is that the keenness of volunteers is precipitating a withdrawal of the EA on the ground… and that's not what you want… the whole [WFD] is set up

> around active community groups: for better or worse we are embracing that philosophy [but] there are serious moral questions'.

This demonstrates a complex tension: on one hand, citizen science can provide new data about environmental problems and support more democratic decision making (Sprain & Reinig, 2018). On the other, it may threaten traditional professional expertise (e.g. Petts & Brooks, 2006), and the transfer of responsibility for environmental monitoring from government to citizens could be morally objectionable. This dilemma suggests effective negotiation between experts and citizens to establish the boundaries of their respective domains is critical (e.g. Lidskog, 2008). Explicitly defining these boundaries may help develop clearer guidelines to define how citizen science data informs decision making, rather than inadvertently replacing or undermining authoritative professional expertise.

8. PROJECT LEADERSHIP AND INDIVIDUAL PERSONALITIES

A clear theme emerging from the data was leadership. The Citizen Crane leadership team (Sarah, James and Linda) was described as essential for the setting the direction of the project, or the 'meaning and thrust of the project' as James put it. Ben echoed this, saying that they had a 'view of where they want this to go'. The leadership team was noted as driving forward decision making, facilitated by being a close-knit group that was 'small, tight, agile… a crystal part of the project' according to James. The leadership team's transparent approach, such as reporting data openly and establishing the project steering group, clearly engendered a sense of trust and openness between the leadership team and stakeholders. This appeared to be of importance for ensuring that data about the Crane were considered legitimate, and reinforced opportunities to enhance the quality of the data gathered.

The success of the leadership team was clearly related to their diverse professional experiences (Figure 2). James's professional work was in environmental consultancy; Sarah worked for a conservation organisation. Both integrated Citizen Crane into their professional work. Sarah explained that she had been involved in London-wide citizen science initiatives, and the pollution event of 2011 presented an opportunity to contribute professional expertise in support of personal interests: 'it's the beautiful point at which the two [professional and personal interests] overlap'. James had strong technical knowledge of river management and water quality gained through a career in environmental consultancy. Citizen Crane drew on this but also engaged his consultancy to undertake work for the project. Although the leadership team had highly complementary skills and interests, their meeting was largely coincidental through social and professional networks.

The personalities of individuals in the steering group and stakeholders were widely seen as important for the success of the project. Ben as described the leadership team as 'very charismatic' and noted that 'a lot rests on individuals'. Sarah noted Linda's 'power' in building stakeholder relationships. Helen reflected more widely on the position and role of individuals and the potential fragility of this: 'it's not the organisation, it's personalities…maybe if that person leaves the relationship breaks down'. She noted the challenges of staff turnover at the EA:

> 'officers often change…every person that comes in, wants to be to the letter of the law but [they are not always] pragmatic; we've been lucky… David's been there… [and the] water quality people have been consistent'.

Linda also remarked on turnover of staff in the water company, but saw this in a more positive light:

> '…[I] had four different contacts in [the water company] in three years… but they're less tied-in to the institutional structure… it is easier to work with younger and more enthusiastic people'.

The importance of individuals, rather than organisations, reflects how current business and operational processes do not easily facilitate using citizen science data. Entrepreneurial individuals (e.g. Westley et al., 2013) were key to championing the use of Citizen Crane data to manage the river more effectively. Social and institutional entrepreneurship (Biggs et al., 2010; Rosen & Olsson, 2013) were evident, such as Linda's work with FORCE and David's championing of the project in the EA. Further research to better identify the characteristics of entrepreneurship in citizen science leaders could help increase the impact of citizen science decision-making.

The nature of the leadership team also provides an insight into the nature of environmental expertise. They were important for providing a conduit between 'non-expert' citizen scientists on the ground and the data they collected, and 'expert' decision-makers. Their interdisciplinary professional expertise and life experience positioned them between the technical experts and lay volunteers (a 'volunteer expert'). This supports the idea that a simple expert/non-expert distinction does not adequately explain the nature of expertise in citizen science (Burgmann et al., 2011; Evans, 2008). Rather, these findings support Lidskog & Sundqvist's (2018) argument that there is no general form of expertise, but that expertise is embedded in specific contexts and facilitated through social infrastructures: in this case the context of a polluted but cared-for urban river, and a social infrastructure of professional relationships with the EA and water company.

9. WAYS FORWARD FOR CITIZEN SCIENCE IN DECISION MAKING

This paper has shown how citizen science has led to a demonstrable change in the management of an urban river through informing business and regulatory practices. Data quality has been of key importance to this change. This research suggests that data quality is dependent on processes beyond checks on the data itself. For example, factors such as alignment with professional standards and sampling methods, and professional engagement with regulators and businesses, contributed to a culture focussed on high-quality data. This was further reinforced by demonstrable changes in the river's management. The leadership team's entrepreneurial approach to building relationships and partnerships with the EA and water company was critical for this alignment, enabling them to negotiate through the boundaries that scientific standards can pose (Ottinger, 2010) and develop a high degree of credibility with the EA and water company.

Greater use of citizen science in decision-making could be facilitated by improved training and guidance for project leaders, particularly on regulatory practices, business processes and stakeholder management. Existing guidance tends to provide useful advice on project management and technical design but less insight into other considerations. Therefore, there may be a role for organisations such as the European Citizen Science Association (ECSA), the British Science Association, WaterUK and other professional bodies to build on existing guidance and advice (e.g. Tweddle et al., 2012). This would be of particular benefit for projects concerned with urban waterbodies where multiple public and private organisations contribute to their management. Water companies and the EA could more widely promote approaches to river monitoring and surveying that produce high-quality and usable data, extending existing resources (e.g. The Rivers Trust, 2016). This would also help foster a culture of transparent partnership working between citizen groups and water companies, which this research has shown to be critical for informing decision-making through enhancing data quality.

Influential individuals played an important role within their institutions in normalising citizen science, informally advocating to colleagues the benefits of Citizen Crane. However, this was largely confined to a local area; colleagues who were more remote from the Crane tended to be more sceptical of citizen science. Formalising a role of 'citizen science champion' as a source of expertise within the EA and other government agencies might help counteract scepticism and find robust ways of embedding citizen science into standard operating practices. A key approach here for river management would be in demonstrating the use of citizen science across multiple catchments. If the positive outcomes of the Citizen Crane project were replicated elsewhere, it would enhance the wider credibility of citizen science and reaffirm the value of multiple sources of expertise for the management of highly-dynamic systems such as urban river environments.

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SUPPORTING INFORMATION

Sample Interview Schedule

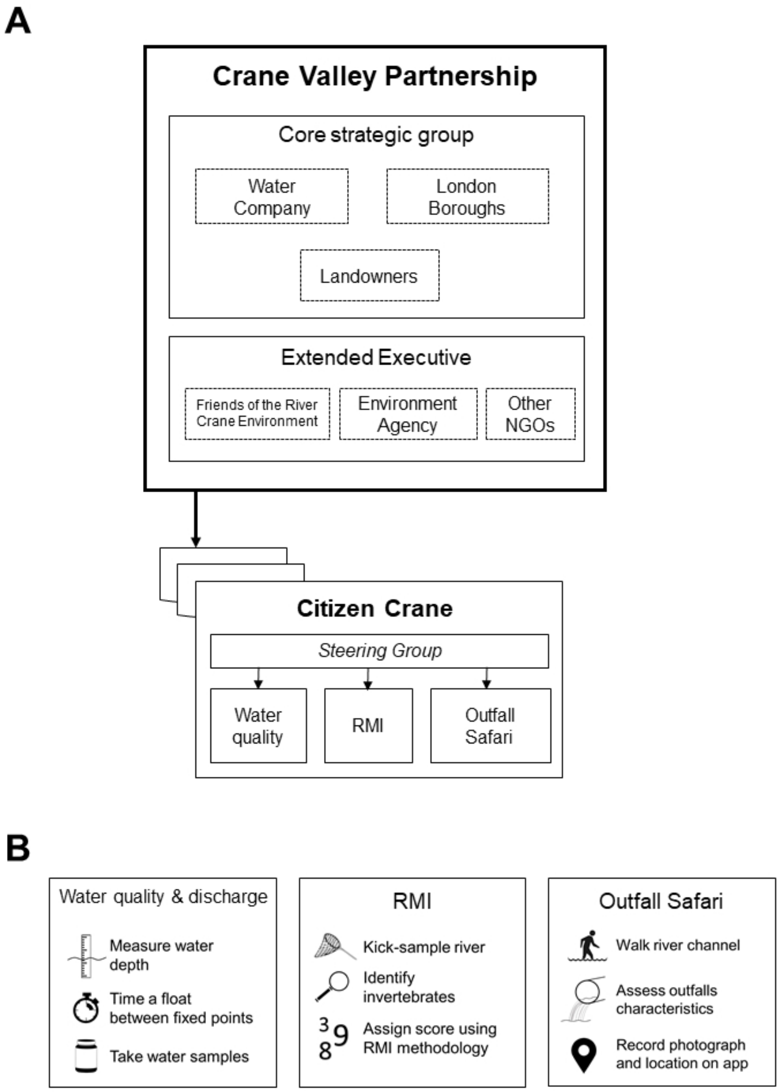

Figure 1: A: Summary of the structure of the Crane Valley Partnership (a full version is available at http://www.cranevalley.org.uk/about/partnership-structure.html). Citizen Crane is one of a number of projects being undertaken on the River Crane. B: Activities undertaken by citizen scientists in each of the components of Citizen Crane (RMI; Riverfly Monitoring Initiative). Water quality and RMI data are collected monthly from 11 sites along the River Crane.

190x275mm (96 x 96 DPI)

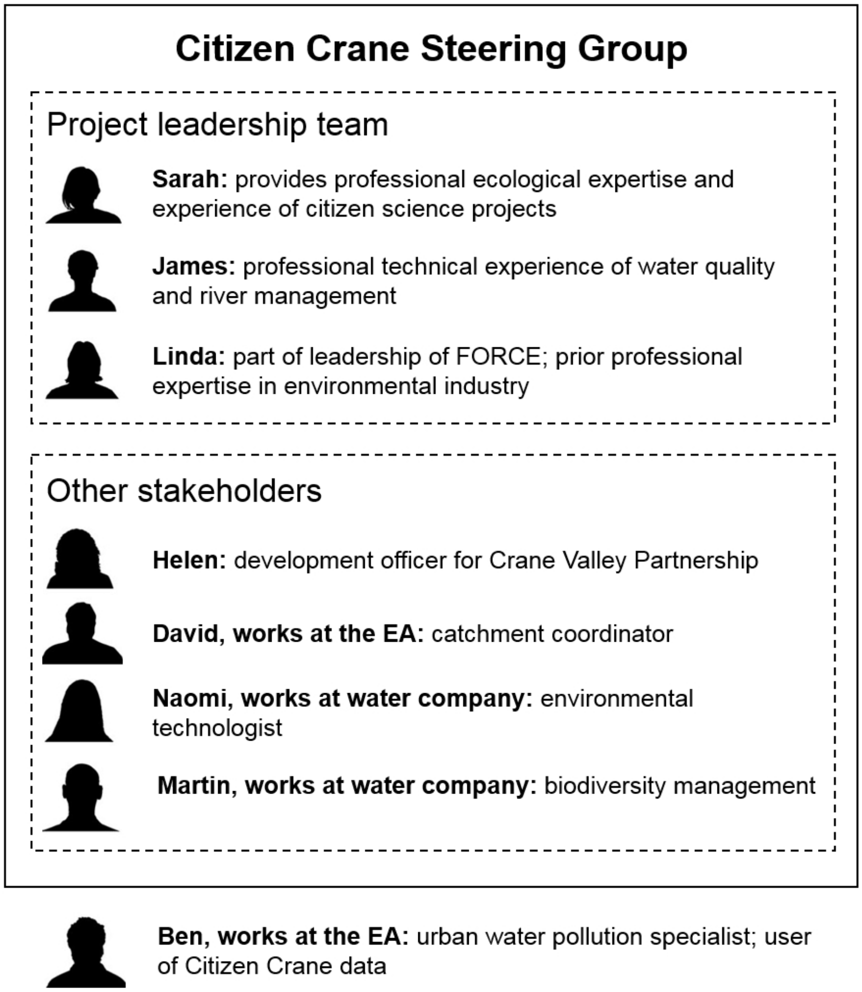

Figure 2: Details of the eight interviewees who participated in the research. All names have been changed.

172x184mm (150 x 150 DPI)