UK Environmental Observation Framework

Understanding Citizen Science and Environmental Monitoring

Final Report on behalf of UK Environmental Observation Framework by:
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Written by scientists at the Biological Records Centre and the Natural History Museum Angela Marmont Centre for UK Biodiversity, on behalf of the UK Environmental Observation Framework.

UK Environmental Observation Framework

The UK Environmental Observation Framework is a partnership of the major public funders of environmental science and was launched in 2008 to address issues of fragmentation, data access and a lack of strategic direction in environmental monitoring.

'Changing the way the UK perceives, values and uses environmental observations'

BRC Biological Records Centre

The Biological Records Centre (BRC) is within the NERC Centre for Ecology & Hydrology and jointly funded by NERC and the Joint Nature Conservation Committee. The BRC, established in 1964, is a national focus in the UK for terrestrial and freshwater species recording. BRC works closely with the voluntary recording community, principally by supporting national recording schemes and societies.

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The Angela Marmont Centre for UK Biodiversity is a hub for amateur naturalists, enthusiasts and other societies studying British wildlife. A place to investigate all aspects of the natural world, from animals, insects and plants to fossils and minerals.

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Contents

Summary

Citizen science can broadly be defined as the involvement of volunteers in science. Over the past decade there has been a rapid increase in the number of citizen science initiatives. The breadth of environmental-based citizen science is immense. Citizen scientists have surveyed for and monitored a broad range of taxa, and also contributed data on weather and habitats reflecting an increase in engagement with a diverse range of observational science. Citizen science has taken many varied approaches from citizen-led (co-created) projects with local community groups to, more commonly, scientist-led mass participation initiatives that are open to all sectors of society. Citizen science provides an indispensable means of combining environmental research with environmental education and wildlife recording.

Here we provide a synthesis of extant citizen science projects using a novel cross-cutting approach to objectively assess understanding of citizen science and environmental monitoring including:

1. Brief overview of knowledge on the motivations of volunteers.
2. Semi-systematic review of environmental citizen science projects in order to understand the variety of extant citizen science projects.
3. Collation of detailed case studies on a selection of projects to complement the semi-systematic review.
4. Structured interviews with users of citizen science and environmental monitoring data focussing on policy, in order to more fully understand how citizen science can fit into policy needs.
5. Review of technology in citizen science and an exploration of future opportunities.

Motivations of volunteers

The willingness of large numbers of volunteers to participate in environmental science projects is inspiring. There have been a number of recent studies on the motivations of volunteers participating in citizen science. The most important consideration is that the motivations of participants differ widely, both within and between sectors of society. It is not easy for users of data to design and develop a citizen science project that meets the needs of all volunteers; indeed such a catch-all approach is rarely useful. Projects must be tailored to match the interests and skill-sets of participants and understanding the motivations and expectations of potential volunteers is crucial to developing successful projects. The most salient motivations are enjoyment and the enthusiasm for the goals of the project. Indeed the importance of aesthetic appreciation, wonder and connection to the natural world are central to involvement. It is also recognised that the depth of involvement and feeling of control over the scientific process is a powerful motivator and can lead to deep, long-lived engagement and high quality of output alike. Further understanding the motivations of the diverse and disparate communities participating in citizen science is critical if we are to maximise the benefits that it can provide to both science and society. Recognition that citizen science offers a range of opportunities to suit people with diverse interests and abilities is contributing to the notion that

participation not only benefits the initiative but also the associated communities and volunteers. It is, though, very easy to make incorrect assumptions on the motivations and interests of different sectors of society.

Semi-systematic review

We scored 234 projects across nearly 30 different attributes. The attributes were of two main types: (1) 'descriptive attributes' (the majority of attributes) on which we sought to assess differences between projects; (2) 'classification attributes' which were prior classifications and we wanted to see whether these aligned to the classification identified with grouping of projects identified from the 'descriptive attributes'. In order to simplify the dataset, for easy interpretation, we used multivariate statistical approaches for data reduction and clustering. In summary the semi-systematic review revealed that the variation in extant citizen science projects can be explained on two main axes, according to their degree of mass participation and their thoroughness. This allowed extant projects to be classified into four main groups, which we ascribed as simple local projects, thorough local projects, simple mass participation projects and thorough mass participation projects. Nearly all citizen science revealed through our search was contributory (established by professionals, and inviting people to contribute data). It was also interesting to note that although citizen science projects that receive the highest profile are national or multinational in scope, many citizen science projects are local in scale. UK projects were disproportionately likely to require high investment according to our classification (that is the project team make a high investment, in terms of provision of support and clarity of aims, and require high investment by volunteers, in terms of complexity of the task and time needed). Indeed the requirement for relatively long visits, repeat visits, and visits to sites that are allocated in advance are strongly associated and there is potential to reduce the volunteer investment (and so possibly increasing involvement) by cutting across these parameters, for example utilising short repeat visits to allocated sites.

Case studies

Detailed case studies of citizen science were used to provide additional information to align with the semi-systematic review and provide in-depth examples of current practice across a range of approaches. Thirty-three citizen science initiatives were selected from the semi-systematic review using a stratified approach to ensure that the case studies represented the breadth and diversity of citizen science. A total of 30 case studies were returned completed. The case studies revealed a strong alignment on the values, design and implementation of citizen science with end-use. Most of the citizen science represented through the case studies involved a contributory approach and generally of observations collated in the field or virtually. It was interesting to note the cost of citizen science was that directly informed policy, for example through development of indicators, was in the region of £70K to £150K per annum. Indeed all citizen science incurs some cost particularly in the initial phases. The diversity of citizen science is evident from the case studies both in terms of geographic scope and range of observations. However, all the case studies highlight the importance of feedback and engagement as a component of citizen science. The many ways in which this is achieved is fascinating and further demonstrates the value of sharing good practice. Social media is increasingly being used as a means of providing rapid and interactive feedback. Equally face-to-face mentoring is commonly used and an effective method of maintaining motivation and engagement of volunteers.

Structured interviews with users of citizen science

There is evidence to suggest that the value of citizen science for monitoring the environment and providing evidence to underpin policy has been underestimated. However, over the last few years there have been a number of publications that demonstrate the utility of citizen science for policy and other purposes highlighting the critical role of volunteer monitoring in providing evidence of environmental change. Citizen science is not always explicitly mentioned but the desire to increase engagement and participation is evident. Interviews of defined end-users (mainly government agencies and government departments) provided an opportunity to add further context to the information collated through the semi-systematic review and case studies. Eighteen citizen science data users or potential users were identified through consultation with the UK-EOF steering group. Interviews were carried out from the end of June to early July 2012 and followed a standard format including introduction to the project, purpose of the interview followed by discussion around 16 questions which were developed to align with the semi-systematic review. The end users recognised the important role of citizen science but the tendency to perceive the quality of citizen science collated information as low could detract from the use of such information. However, the semi-systematic review and case studies provide strong evidence that the perception of citizen science as providing low quality information is misguided and that considerably more could be made of citizen science by end users than is currently the case.

Review of technology

Technological advances have increased the accessibility of citizen science and, hence, the number of volunteers contributing to a diverse range of citizen science initiatives at various spatial scales has also increased. Here we describe some of the roles that technology can play in citizen science, focussing both on methods for data collection and visualisation and on the opportunities for the design of databases for enhanced data sharing. We finish by considering risks of using technology. Websites have become the mainstay of citizen science projects but that there is an increasingly wide range of additional technology that could support citizen science, including smartphones with the use of GPS for accurate geographical locating or in-built or plug-in sensors. Visualisation and use of data in real time is one of the key ways to enthuse and motivate volunteers. However, reliance on relatively novel technologies could exclude potential participants.

The data collected for many citizen science projects are highly specific to that project. However, a greater vision for citizen science is the sharing and integration of data perhaps linking through 'cyber-infrastructures' (database systems that are inter-operable and ensure consistent data standards). Already many citizen science projects are using crowd-sourcing for the collection or analysis of data. Additionally social networking technology can permit the creation of virtual communities and can be especially important for providing support in citizen science projects in which people are geographically dispersed.

There are a number of risks associated with increasing use of innovative technology. Perhaps the biggest danger of using technology in citizen science is that not everyone is able or willing to engage. Additionally, as the ease of establishing new projects increases with technological innovations and the maturity of website technology, there is the risk that this drives a plethora of projects causing confusion or fatigue among potential contributors. Any attempt to control the growth of citizen science, even if feasible, would go against the increasing drive towards the principles of open science and crowd-sourcing. Technological innovations often come at a financial cost, so the usefulness of such innovations needs to be assessed for each project individually on a project-by-project basis.

Conclusions

Volunteer participation with environmental science and natural history has a long history, especially in Britain, long before it was termed 'citizen science'. However, the development of communication technologies through the internet has allowed the flourishing of citizen science. Citizen science has vital roles in scientific research and engagement/education, but it also has the potential to help meet the demands of environmental/biodiversity monitoring, giving it a clear relevance to policy. The advent of new technologies provides exciting opportunities and will ensure greater utility of the data currently collated through citizen science. Here we have highlighted lessons that can be learnt from current citizen science, with a review of extant projects, interviews with potential end-users of the data, and a review of technology that can assist citizen science. We acknowledge the importance of sharing good practice and have provided an accompanying guide on the practical implementation (Tweddle, Robinson, Pocock *et al.*, 2012).

1.0 Introduction

Citizen science, broadly defined as the involvement of volunteers in research (Dickinson, Zuckerberg & Bonter, 2010), has a long history (Silvertown, 2009). In the UK the fields of biodiversity (particularly botany), meteorology and astronomy have been leading the way. The links between climate and biodiversity have been explored extensively through phenology studies including data collated by volunteers for hundreds of years (Amano, Smithers, Sparks *et al.*, 2010, Sparks, Jeffree & Jeffree, 2000, Miller-Rushing, Primack & Bonney, 2012). Indeed the recording of the timing of seasonal plant events has long been a pastime amongst natural historians in Britain with records going back to the 1730s (Sparks & Carey, 1995). The use of citizen science for astronomy has an equally impressive history. In 1874 the British government funded the Transit of Venus project to measure the Earth's distance to the sun engaging the admiralty and amateur astronomers to support data collection all over the globe (Ratcliffe, 2008). The legacy of citizen science in astronomy is also evident in modern day projects (for example, Galaxy Zoo; http://www.galaxyzoo.org/).

The past decade has seen a rapid increase in the number of citizen-science initiatives available globally particularly in North America and Europe (Bonney, Ballard, Jordan *et al.*, 2009a, Mackechnie, Maskell, Norton *et al.*, 2011, Silvertown, 2009), spanning diverse areas of interest and ranging from local to global (Silvertown, 2009, UK-EOF, 2011, Dickinson *et al.*, 2010, Bonney, Cooper, Dickinson *et al.*, 2009b, Nov, Arazy & Anderson, 2011). Biodiversity monitoring lends itself to citizen science, so it is perhaps unsurprising that wildlife-focussed projects dominate the profile of citizen science initiatives (Dickinson *et al.*, 2010). Indeed eBird highlights the high-level of participation in ecological citizen science collecting 2 million to 3 million new species-date-location records monthly from across the globe (Sullivan, Wood, Iliff *et al.*, 2009). Aside from astronomy, there are many examples of successful physical and social science-based programmes, including those focussing on climate (for example, Weather Observation Website), water (for example, Creekwatch, OPAL Water Survey and Anglers' Monitoring Initiative), habitats (for example, MCS Beachwatch) and local understanding (for example, Extreme Citizen Science - ExCiteS).

The breadth of environmental-based citizen science is immense. Citizen scientists have surveyed for and monitored a broad range of taxa, and also contributed data on weather and habitats reflecting an increase in engagement with a diverse range of observational science. However, while the contribution of data in the form of observations (species, habitats, water quality etc) is the most common form of involvement, there are a few examples whereby physical samples, such as insects on yellow sticky traps (Gardiner, Allee, Brown *et al.*, In press), or dead predatory birds (Walker, Shore, Turk *et al.*, 2008) and water samples (such as Columbia River Keeper www.columbiariverkeeper.org), are submitted. Citizen science has taken many varied approaches from citizen-led (co-created) projects with local community groups (for example, Riverfly Partnership www.riverflies.org), to, more commonly, scientist-led mass participation initiatives that are open to all sectors of society (for example, Conker Tree Science www.ourweboflife.org.uk and OPAL Bugs Count www.opalexplorenature.org/bugscount). Citizen science provides an indispensable means of combining ecological research with environmental education and wildlife recording (Dickinson, Shirk, Bonter *et al.*, 2012).

In the UK the rich history of wildlife recording by expert volunteers is particularly evident. Such expert volunteers have been making a major contribution to the documentation of change within the UK's biodiversity and wider environment especially, since the seventeenth century. Many volunteers now work with organisations such as the Biological Records Centre (BRC), British Trust for Ornithology (BTO) and the Marine Biological Association (MBA) and share data through the National Biodiversity Network (NBN) Gateway. However, it is only relatively recently in Britain that such volunteer activity has been placed within the context of citizen science. The growth of citizen science is, in part, a consequence of this re-branding. However, perhaps more pertinent is the realisation that both economic and logistical factors prevent scientists alone from generating the volume of data (i.e. both large extent and fine resolution spatially and temporally) that they need for a complete understanding of the natural environment. Other drivers for this rapid expansion include a growing confidence in the scientific accuracy and validity of public-generated datasets (Crall, Newman, Jarnevich *et al.*, 2010) and evidence of their use as valuable sources of information for addressing critical scientific (Levrel, Fontaine, Henry *et al.*, 2010, Roy, Adriaens, Isaac *et al.*, 2012a, Hochachka, Fink, Hutchinson *et al.*, 2012, Losey, Perlman & Hoebeke, 2007) and policy-relevant questions (EEA, 2012, Defra, 2012, Defra, 2011). The wealth of technology available to support and inspire new citizen science initiatives and opportunities is rapidly expanding (Newman, Wiggins, Crall *et al.*, 2012) and has enabled citizen science to become global in scale, long-term in ambition and engage hundreds of thousands of volunteers in many different scientific pursuits (Hochachka *et al.*, 2012).

1.1 Defining citizen science

Citizen science is increasingly used as an overarching term for the many varied approaches utilising volunteers in science, from active participation in hypothesis-led science through to passive movement of sensors; from addressing highly-focussed questions to educational exercises generating data of little scientific value; from using people as data collectors to participants forming the projects, assessing the data and using the information themselves. Citizen science is a broad concept. Numerous definitions of citizen science have been proposed. Here, we base our definition of citizen science on the UK Environmental Observation Framework (UK-EOF) recommendation (UK-EOF, 2011), which recognises the inconsistent use of the term, and so we define citizen science as "volunteer collection of biodiversity and environmental data which contributes to expanding our knowledge of the natural environment, including biological monitoring and the collection or interpretation of environmental observations" . Citizen science invites people to participate in both scientific thinking and data collection (Cooper, Dickinson, Phillips *et al.*, 2007), of both observations and physical specimens, and so one valuable way of categorising citizen science (Bonney *et al.*, 2009a) is:

"volunteer collection of biodiversity and environmental information which contributes to expanding our knowledge of the natural environment, including biological monitoring and the collection or interpretation of environmental observations".

Contributory projects – designed by professional scientists; members of the public primarily contribute data.

Collaborative projects - designed by professional scientists; members of the public contribute data and inform the way in which the questions are addressed, analyze data and disseminate findings.
Co-created projects - designed by professional scientists and members of the public working together and for which some of the volunteer participants are involved in most or all steps of the scientific process.

We recommend expanding the definition of citizen science beyond the contributory model to include collaborative and co-created projects which engage volunteers beyond the collection of environmental observations. An additional fourth approach should also be considered in which members of the public work together on all stages of the project without involvement of professional scientists. Such a model is characteristic of, for example, local biodiversity atlas projects in Britain.

1.2 Aims

Given the scope and number of citizen science projects, it is helpful to understand the current 'landscape' of citizen science in order to learn lessons and identify opportunities. Such a synthesis of extant citizen science projects has not, thus far, been carried out and so we employ a novel cross-cutting approach to objectively assess understanding of citizen science and environmental monitoring including:

6. Brief overview of knowledge on the motivations of volunteers.
7. Semi-systematic review of environmental citizen science projects in order to understand the variety of extant citizen science projects.
8. Collation of detailed case studies on a selection of projects to complement the semi-systematic review.
9. Structured interviews with users of citizen science and environmental monitoring data focussing on policy, in order to more fully understand how citizen science can fit into policy needs.
10. Review of technology in citizen science and an exploration of future opportunities.

We explore the degree of overlap between data provided through citizen science and the needs of data users. From this we outline key recommendations and suggestions for developing citizen science approaches within the UK. Additionally we critically review the opportunities presented by existing and emerging technologies. We used this information to develop a guide to support the development, delivery and evaluation of biodiversity and environment-based citizen science within the UK (Tweddle *et al.*, 2012).

1.3 Motivation of volunteers participating in citizen science

The number of citizen science projects across Europe (http://eumon.ckff.si/aims.php) and North America (http://www.birds.cornell.edu/citscitoolkit/) is impressive. The willingness of large numbers of volunteers to participate in environmental science projects, as exemplified through OPAL (www.opalexplorenature.org) (Davies, Bell, Bone *et al.*, 2011), is inspiring. There have been a number of recent studies on the motivations of volunteers participating in citizen science (O'Brien, Townsend & Ebden, 2008, Grove-White, Waterton, Ellis *et al.*, 2007, Nov *et al.*, 2011) and we provide a brief review here.

The most important consideration is that the motivations of participants differ widely, both within and between sectors of society (Ellis & Waterton, 2005, Ellis, Waterton & Wynne, 2010, Grove-White *et al.*, 2007, Miller-Rushing *et al.*, 2012). It is not easy for users of data to design and develop a citizen science project that meets the needs of all volunteers; indeed such a catch-all approach is rarely useful. Importantly, the protocols that provide the optimal data for users (scientists, policy-makers and other end-users) often do not translate to a citizen science project that is achievable in practice, because the resulting project either is unattractive to the desired participants or makes too great a demand on the volunteer (for example demanding frequent visits to distant sites or involves protocols that are too complex or time-consuming). Projects must be tailored to match the interests and skill-sets of participants and understanding the motivations and expectations of potential volunteers is crucial to developing successful projects.

In a recent survey of volunteers to Stardust@home, a digital citizen science project in which volunteers classify on-line images from NASA's Stardust spacecraft, it was found that the most salient motivations were enjoyment and the enthusiasm for the goals of the project (Nov *et al.*, 2011). Another important insight from this survey was the need to create an environment in which volunteers can progress from straightforward tasks to more complex tasks and responsibilities. The governance and decision-making within citizen science projects is often the responsibility of the scientists managing the projects but the need for empowerment of volunteers in governance is evident.

The motivations of diverse UK communities participating voluntarily in the delivery of UK Biodiversity Action Planning (BAP) through biological recording was examined by the "Amateurs to Experts" project (Grove-White *et al.*, 2007). The primary motivations of national schemes and societies (highly skilled individuals often termed 'amateur experts') involved the traditional elements of natural history (pleasure of finding, observing, identifying, recording and creating inventories of organisms). Similarly Natural History Societies and Wildlife Trusts were motivated by the intrinsic enjoyment of natural history and additionally by contributing to the protection of local species and habitats. In contrast participants new to biological recording were primarily motivated by the pleasure of being in the natural environment and volunteers working with Non-Governmental Organisations (NGOs) were motivated by protection of habitats and species coupled with creation of campaigns.

The "Amateurs to Experts" project emphasised the importance of aesthetic appreciation, wonder and connection to the natural world to all participants involved in the UK BAP and suggested that these "*instead of being peripheral issues, could actually work as a bond between naturalists and conservation agencies*" (Grove-White *et al.*, 2007). Indeed the anglers considered within the "Amateurs to Experts" project were motivated by conservation aims and the will to provide evidence on water quality to the Environment Agency. Likewise, ramblers included in this same study were motivated to do something they considered of value (recording Elm trees), in addition to their primary recreational pursuit (walking). There is a willingness of some volunteers to contribute to conservation action that is driven by statutory bodies but volunteers would benefit if all the relevant bodies could work together in developing and communicating citizen science projects (personal communication, SEPA workshop 2012). The aim of such collaboration would result in reduced competition for participants and consistency of approach, but not a standardised, homogenised approach to citizen science. However, it is important to recognise that not all volunteers are willing to collect data for policy-needs (Grove-White *et al.*, 2007) and some (biodiversity recorders) report "a deep sense of alienation and frustration provoked by the realisation that their data was not being used towards the ends hoped for" (Grove-White *et al.*, 2007).

One key insight, highlighted throughout studies considering the motivation of participants, was the importance of maintaining strong links between the data and data providers, both for conceptualising the research but also for encouraging future participation. This can take many forms from feedback and incentives to involvement in data analysis and interpretation. Many citizen science initiatives use spatial maps to display data as it arrives and so provide immediate information on how the participants contributions are closing gaps in knowledge (Hill, Guralnick, Smith *et al.*, 2012). Incentives such as digital badges (for example used in Notes from Nature and iSpot) can be assigned in recognition of specific achievements. However, rigorous studies exploring the effectiveness of badges as incentives to enhance citizen science motivation and continued contribution have yet to be conducted (Hill *et al.*, 2012). Several projects also use new media (e.g. blogs, and increasingly social media) to continue communication with participants. Even for those not interacting directly, they get an impression of the activity within the project. Very few studies involve the volunteer participants in analysis and interpretation of data although within biological recording this is common practice. Volunteer scheme organisers can play a critical role in the interpretation of results derived from distribution data. The depth of involvement and feeling of control over the scientific process is a powerful motivator and can lead to deep, long-lived engagement and high quality of output alike.

Further understanding the motivations of the diverse and disparate communities participating in citizen science is critical if we are to maximise the benefits that it can provide to both science and society. Recognition that citizen science offers a range of opportunities to suit people with diverse interests and abilities is contributing to the notion that participation not only benefits the initiative but also the associated communities and volunteers. It is acknowledged that citizen science which fosters community involvement in decision-making and develops partnerships is likely to thrive and, indeed, increase capacity (O'Brien *et al.*, 2008).

There is still a long way to go if we are to truly democratise citizen science. As a general rule, communities and demographics that are not fully engaged with science are also hard to reach from a citizen science perspective (Tweddle & Scott, 2009). These include Black and Minority Ethnic communities and lower socio-economic groups, collectively representing over half of the UK population (FreshMinds, 2007). Given that many of these communities are disproportionately represented within urban centres, this is a cause for concern. It is also an indication of the potential that engaging with these demographics can bring in terms of increasing scientific literacy within the UK population, monitoring environmental change within urban environments, or helping to build our understanding of the effects that urbanisation has on our environment and on biodiversity. Understanding the cultural, social, economic and physical barriers that currently inhibit engagement with citizen science remains complex (Tweddle & Scott, 2009), and the results of the OPAL project are awaited with anticipation. It is, though, very easy to make incorrect assumptions on the motivations and interests of different sectors of society and the value of engaging community leaders at an early stage in the developmental process, and the powerful motivational role that they can have on their peers, cannot be underestimated in this context.

In summary:

- Volunteers are motivated by enjoyment of participation but also by having confidence in the utility of the data. Initiatives with specific aims for underpinning policy or contributing to hypothesis-driven research would be welcomed by, at least, some of the citizen science community.
- It is important to respect the diverse motivations of volunteers. For example, not all will be willing to modify their existing activities to engage with policy-relevant citizen science. Additionally, in some case citizen science requests may be considered relevant for professional consultancy rather than volunteer participation. Citizen science should be innovative and imaginative combining the collation of high quality and useful data while appealing to the volunteer community.
- Providing opportunities, such as training and mentoring, for volunteers to increase their skills and expertise is important, especially for projects that are not aiming to be mass participation.

2.0 Semi-systematic review

In order to more completely understand the variety of citizen science projects, we undertook a systematic (hence repeatable) search and reviewed these projects, according to pre-defined attributes. This allowed us to describe the variety of citizen science projects, which attributes were most important in explaining this variety, and how projects could then be classified.

2.1 Approach to the semi-systematic review

In total we included 234 projects in our analysis (details of analysis method described in Appendix 1). We scored each project on the basis of many specific attributes (Table 1) that we could assess from publically-available information. We chose to keep our scoring simple (typically yes/no responses or with few ordinal categories) in order to assist with the reliability of the scoring. In essence we were scoring how projects appeared based on information in the public domain (usually the project website). This, therefore, limited the attributes that we could score. For instance we could not reliably assess the source of funding, amount of funding received, the motivation of the project leaders, or the 'success' of the project. Therefore, our approach complements the studies of Wiggins and Crowston (2011, 2012) in which project representatives were invited to assess their own projects. This self-assessment provides more information on the intentions of the project leaders (which may be idealised rather than actualised) and a thorough enquiry of the projects (Wiggins & Crowston, 2012b, Wiggins & Crowston, 2011, Wiggins & Crowston, 2012a). This can also be achieved through the case studies that we collected as part of this study, as described below. The value of our standardised review based on information in the public domain, despite its limitations, is that it allowed a much larger number and, potentially, a wider and more representative range of projects to be assessed than would otherwise be possible.

Nearly 250 projects, scored across nearly 30 different attributes created a lot of information, but such information is difficult to interpret as a whole. The attributes were of two main types: (1) 'descriptive attributes' (the majority of attributes) on which we sought to assess differences between projects; (2) 'classification attributes' which were prior classifications and we wanted to see whether these aligned to the classification identified with grouping of projects identified from the 'descriptive attributes'. In order to simplify the dataset, for easy interpretation, we used multivariate statistical approaches for data reduction and clustering. Data reduction is a standard approach (e.g. applied in principal components analysis) in which many different variables are reduced to a few important axes, each of which is a combination of the original variables. Data reduction provides a simpler representation of the data based on the initial variables that are most important in explaining variation between the data points. Secondly, we undertook cluster analysis, in order to identify the number of different types of project, based on the results of the data reduction. This is valuable because it allows discrete types of project to be identified. Specifically, we used multiple factor analysis for data reduction and hierarchical cluster analysis, selecting the most informative number of clusters. We did not include in the multivariate analysis the 4% of projects that were entirely computer-based because many of the questions were not applicable, thus giving a final sample size of 234 projects.

2.2 Summary of results

Data reduction and clustering

We undertook multiple factor analysis (MFA, outlined in Appendix 1) on the descriptive attributes. The resulting first two dimensions of the MFA explained a total of 22.1% of the variance. This is a relatively low proportion of the total variance and indicates that there was substantial variation in the attributes of the projects which could not be easily simplified. We assessed which attributes were strongly associated with the first two dimensions of the results of the MFA (Table 1; Appendix 1).

- **First dimension** (explaining 11.8% of variance). We interpreted the first dimension as the ***degree of mass participation***; contrasting mass participation projects (high values) and local monitoring projects (low values).
- **Second dimension** (explaining 10.3% of variance). We interpreted the second dimension as the ***'degree of investment'*** of the project (both the investment of the project managers in providing clear aims, good background information and good supporting material, but also the investment required by the participants in spending time and addressing many different types of data question. It contrasts 'simple' with 'thorough' projects. Note that this is not based on the level of financial investment (which was unknown to us across these projects) and we are not judging the success of the project. We explicitly acknowledge that 'simple' projects may have a good fit-to-purpose.

Table 1. Substantial correlations (|*r*|>0.4) of attributes of citizen science projects with the first three dimensions in the multiple factor analysis (MFA). These show how attributes tend to vary along the axes. The full results are listed in Appendix 1. We summarised the two dimensions as degree of mass participation and level of investment.

Dimension	Attribute	Low score	High score
1	Geographic scope	Narrow	Wide
	Selection of sites	Pre-selected	Self-selected
	Snapshots	Not sufficient	Sufficient
	Repeat visits	Required	Not required
	Personal training	Provided	Not provided
	Supporting material on website	Not provided	Provided
	Special equipment	Required	Not required
	Quality of data viewable	Poor	Good
	Viewable data	Static	Dynamic (regularly updated)
	Involvement through smartphone	No	Yes
	Involvement through personal contact	Yes	No
	Photo requested	No	Yes
2	Aims stated	Poor	Good
	Background provided	Poor	Good
	Registration required	No	Yes
	Supporting material on website	Not provided	Provided
	Targeted at school children	No	Yes
	Types of data question	Few	Many
	Involvement via a website	No	Yes
	Best quality of data requested	Lower	Higher

Based on the results of the MFA, we performed hierarchical clustering and identified three main clusters of projects (Figure 1). The clusters provide a usefully classification of the projects, even though the clusters are not highly distinct from each other. We found that the third dimension of the MFA was relatively uninformative in the clustering, so we restrict our summary of the clusters to the first two dimensions.

- Cluster 1 is characterised by negative scores in the first two dimensions, and so represents ***simple, local projects***.
- Cluster 2 is characterised by negative scores in the first dimension and positive scores in the second dimension, and so represents ***thorough, local projects***.
- Cluster 3 is characterised by positive scores in the first two dimensions, and so represents ***thorough, mass participation projects***.
- Cluster 4 is characterised by positive scores in the first dimension and negative scores in the second dimension, and so represents ***simple, mass participation projects***.
- As well as identifying the attributes associated with the two dimensions of the MFA results (Table 1; Appendix 1), we were also able to identify how different aspects of attributes were distributed across the four clusters (Appendix 1; discussed below).

We emphasise that these cluster names are used for convenience to interpret the multivariate summary of the data. We do not claim that all projects in cluster 1 are 'local', but that they share attributes that are negatively associated with the MFA dimension 1, which for convenience we term 'the degree of mass participation'. We also emphasise that the term 'simple' is not used in any way to assess the value of the project, or its fit-to-purpose. We recognise that simple projects requiring relatively low investment can provide valuable data.

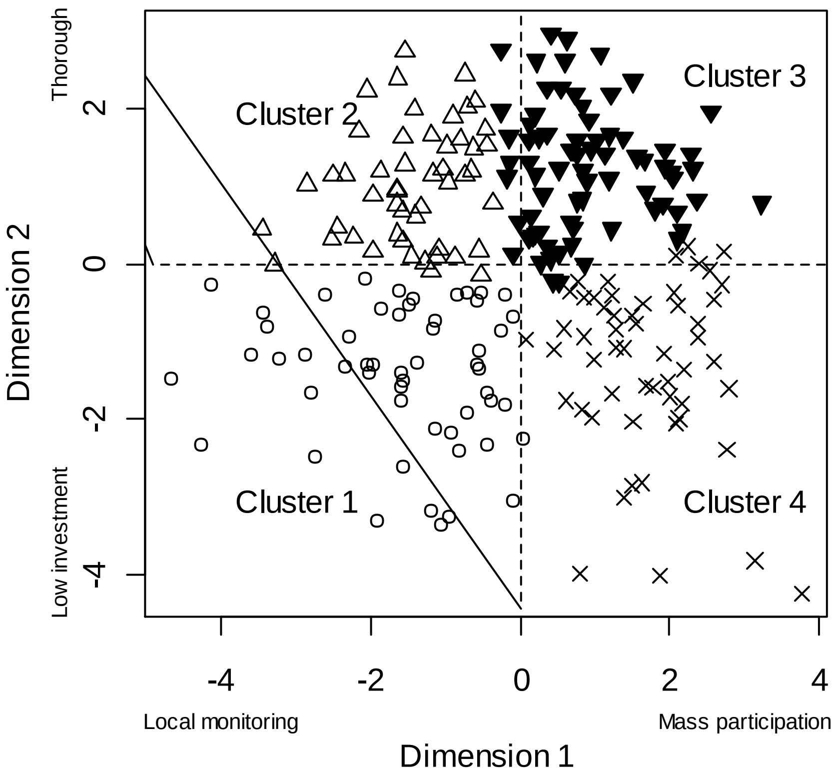

Figure 1. Plot of the 234 analysed projects in the first two dimensions of the multiple factor analysis (MFA). Clusters are identified by the different symbols.

Limitations of our systematic search

We recognise that by searching for projects tagged as 'citizen science' we may have overlooked a large number of projects, especially long-established initiatives in Europe (such as recording animals and plants and collecting phenological records) that may not (yet) regard themselves as 'citizen science'. The lack of citizen science projects from developing countries could be a true reflection of the activity. However, it could equally be a perceived bias which reflects the use of the term 'citizen science', especially in the USA and to a growing extent in the UK, whereas the term may not be used commonly elsewhere for projects involving participatory research. There certainly are excellent examples of projects that could be classified as citizen science within developing countries (such as farmer participatory research (Okali, Sumberg & Farrington, 1994) and ethno-botany (Cotton, 1996)). Understanding and interpretation of citizen science as a term may simply be too limited and narrow in definition. A more inclusive definition than that currently used (e.g. the very recent, but increasing use of the term 'participatory research') may provide a better reflection of the diversity of volunteer participatory research and increase the sharing of concepts and good practice. However, participatory research has only recently (2012) been applied to what we think of as 'citizen science'. It is a term generally applied by academics reflecting on this subject, rather than used by practitioners. Therefore, we did not use it as a search term for this study.

Geographic scope

We found a huge diversity in the scale of citizen science from single, small sites to projects with international scope. However, the majority of the projects we reviewed (38%) have a national scope. It is worth noting that the 'regional' projects (25%) tended to be restricted to specific states in the USA, so within a local government region. Local initiatives (e.g. based in natural parks, nature reserves or small river basin) represented about 14% of the projects reviewed in our study. We suspect that we under-sampled projects that had a local scope. We suspect that local projects will tend to have less of a presence on the internet, a supposition supported by the projects with small geographic scope being associated with providing personal support rather than supporting material on a website.

There is clearly a need for projects operating at many scales both from the perspective of the volunteer participants (who may wish to be involved in a local community-based initiative or may aspire to contribute to a global initiative) versus the end-user (who may wish to have data for a single river catchment or need trends at a national or regional scale). Projects could be developed to offer flexibility in scale of delivery, or different projects designed to meet different spatial requirements. For example, surveillance and monitoring of non-native species is critical and relevant at the global scale but a volunteer may be motivated to participate only at a local scale. Indeed within the UK there are many local action groups working intensively within a small area (for example village, town or river stretches) to monitor non-native species. The value of their involvement is recognised and on-line recording is being developed nationally through the GB Non-Native Species Information Portal (www.nonnativespecies.org) using iRecord (www.brc.ac.uk/iRecord) but with the flexibility to deliver as a web service to community websites.

Scope of observations

Firstly we consider our prior classifications of projects and then we consider the descriptive variables of the reviewed projects.

Domain of research. The majority of the projects that we reviewed were focussed on terrestrial environments (64%), with most of the remaining being focussed on marine/shore (14%) and freshwater (16%). Terrestrial projects were distributed as expected across the three clusters that we identified with the multivariate analysis. However, we found that marine/shore projects were disproportionately likely to be thorough, local or simple, mass participation projects (clusters 2 and 4), rather than thorough, mass participation projects (cluster 3), suggesting an opportunity for marine scientists, especially as marine citizen science was identified as having high potential by the MBA (MBA, 2012). Freshwater projects were disproportionately likely to be thorough, local projects (cluster 2), which matches with the scale and need of the data; many freshwater projects in the USA are legislative monitoring of individual water courses by volunteers, while terrestrial projects with disproportionately unlikely to be in this cluster. Projects functioning across all domains were most likely to be simple, mass participation projects (cluster 4).

Contributory, collaborative and co-created. The vast majority of projects that we reviewed were contributory (96%). We found that projects that were classified as collaborative or co-created were disproportionately likely to be local projects (clusters 1 and 2); the local geographic scope makes the creation of such projects more likely. However, given the benefits of including participants in the development and governance of citizen science (Grove-White *et al.*, 2007), we anticipate that collaborative and co-created projects will increase. Additionally new technologies are anticipated to overcome some of the challenges of establishing and sustaining projects that follow these more complex models.

Biodiversity versus environmental science. The majority of projects that we reviewed were focussed on biodiversity (79%) rather than non-biodiversity aspects of the environment. Although we do not have evidence for this, we believe that this is a fair representation of the state of citizen science. There was a slight tendency for environmental projects to be disproportionately likely to be thorough, local projects (cluster 2, e.g. water monitoring).

Region. Nearly two-thirds of projects had a North American focus, mostly the USA (48% of all projects reviewed). Nearly one-quarter of all projects had a UK focus, and 14% had a multinational focus. Multinational projects were, partly by definition, disproportionately likely to be mass participation projects (clusters 3 and 4). UK projects are disproportionately unlikely to be thorough projects (clusters 2 and 3), despite several high-profile projects (e.g. OPAL) that would fit in these clusters. From this review we cannot ascertain whether this is due to lack of appetite by audiences (unwilling to make investment required) or an unwillingness by those setting up projects to make large demands of participants and/or invest in providing clear aims and background context for participants.

Type of projects. Prior to the multivariate analysis, we classified the projects into nine categories, based on whether they were 'recording' or 'monitoring' ('monitoring' being used to describe projects which had a relatively long-term commitment). The majority of projects were classified as biodiversity recording (35%) and biodiversity monitoring (31%). Smaller numbers were classified as water monitoring (7%), environmental (non-water) recording (8%) and monitoring (5%). A smaller number were clearly hypothesis-led science (6%), phenology (3%), technology-focused (3%) or crowd-sourced classification tasks (2%). Projects that we classified as 'recording' or technology-focussed were disproportionately likely to be simple mass participation projects (cluster 3). Biodiversity monitoring was disproportionately likely to be thorough local projects (cluster 2); a surprising finding given the wealth of UK-based biodiversity monitoring projects, but resulting from the large number of projects recruiting volunteers to monitor biodiversity in individual sites and reserves in the USA, which was also the case for water monitoring projects. Phenology and hypothesis-led science was disproportionately likely to be thorough mass participation projects (cluster 3), indicating their value is based on participation at relatively large spatial scales.

Governance and organisation

Lead partner and number of partners. Most projects that we reviewed were led by academics (42%) or non-governmental organisations (NGOS, so including the breadth from local communities to large charities; 41%). Few were led by government agencies (15%) and very few were led by commercial organisations (1%), although 16% of projects did have at least one commercial partner. About a half of projects were led by one group (56%), 16% of projects had one additional partner, 18% had two and 10% had three or more. Simple, local projects (cluster 1) tended to be under-represented by projects led by academic groups and over-represented by projects led by government agencies. Projects led by commercial organisations were highly likely to be simple, mass participation projects.

The top-down approach, through contributory citizen science projects, in part explains the dominance of academic institutes in leading the development of projects. However, non-government organisations (NGOs), ranging from large scientific bodies (notably the British Trust for Ornithology) and large charities (e.g. Audubon Society) to interested individuals (e.g. Dragonfly Swarm Project), offered a similarly high number of projects. Government agencies often provide funding (and are included as project partners) even though they may not lead projects. Remarkably the vast majority of projects had only one partner involved (although we recognise that this may not be a true reflection because in some cases projects were given a single brand, behind which stands a large number of partners). There is definitely an opportunity to increase the collaborative nature of citizen science across the community of interested parties including volunteer participants, scientists, funding bodies, statutory agencies and beyond.

Health and safety. We were only able to find health and safety information provided by 19% of projects, and only for 10% of projects was this comprehensive. We note that health and safety information may have been given for those projects in which personal training was provided, but we could not record this. Comprehensive health and safety information was never provided for simple mass participation projects (cluster 4). We expect that this is largely because such project were designed to be widely accessible and so did not require health and safety information to be given. Where personal training is provided, we expect that health and safety information would also be given, since the organisations have a higher duty of care in such cases.

Project design

Project protocols. The projects we reviewed differed tremendously in the commitment required by the volunteer. One of the most important sets of attributes in explaining the variation among projects was in their design. Specifically mass participation projects (high scores on the 1st dimension of the MFA) tended to allow participants to select their own sites, did not require repeat visits and did not require that participants spent a long time at their site ('snapshots' were sufficient). In the extreme, such an approach treats people simply as mobile, widely dispersed data collectors. At the other extreme, there is the high quality 'monitoring', in which sites are pre-selected (e.g. due to prior requirements or according to a sampling design), and relatively long visits (e.g. more than 5 minutes) are required on a repeated basis. For some projects a snap-shot (one brief visit to one site) was sufficient while for others repeat visits to pre-determined sites were required. Where participants are sufficiently motivated to take part at pre-defined sites (e.g. the randomised sites of the UK Breeding Bird Survey or local surveys at specific natural reserves) then the protocols tended to demand more from the volunteer (repeat visits, and longer involvement per visit).

Effort required and level of engagement made. We assessed the complexity of the task being asked of the participants and found that these attributes also matched with the level of investment made by the project team.

Attributes related to the level of investment (made and required) were strongly related to the second dimension in the MFA, explaining the 'thoroughness' of the projects. Most projects required at least a moderate degree of effort from participants asking a few different types of data question (44%), with 37% asking more than six different types of question and only 19% asking just one type of question. The majority of projects also ask for a least one qualitative piece of data (65%), such as a count or measurement. Many also require that visits are intentional, given the requirement for 'special equipment' (i.e. anything not usually carried) by 52% of projects, but this is strongly associated with local projects rather than mass participation projects. Many projects complement this by providing content-rich background information (45%), which is easy to do with websites. However for 15% of projects the background context was minimal, although this may have been because personal contact is the main way of recruiting, retaining and enthusing volunteers. Although 60% of projects made their aims clear, we considered that 37% of projects provided vague aims and 3% listed no aims. We strongly recommend that aims and the use of the data are stated clearly in citizen science project, since it is the usefulness of the data that sets citizen science apart from simple public engagement projects.

Data required. Most projects required data to be submitted on the location (92%) along with some type of score (88%). A smaller proportion required a photograph to be submitted (32%), although this was associated with the first dimension in the MFA, so indicating that mass participation projects were more likely to require photos. One reason for this may be the ease of validating records which may come in from otherwise unknown people, and strongly associated with this is the ease of submitting photos via smartphones, thus demonstrating how technological advances can be utilised by citizen science. A small proportion of projects required multimedia data (5%; e.g. sound files) or physical samples (10%; often water samples for later analysis by labs) to be submitted.

Engagement and support

Routes to involvement. Most projects used websites as a major route to involving people in the project (78%), for most of the remainder, the website simply served as a port to direct people to further information. A substantial minority used smartphones (13%) and social media (9%) as a route to involvement. We would anticipate that these figures would increase rapidly over time. Few projects appeared to use email (5%) or SMS (text message; 3%) as a route for people to get involved. Email may be used widely to inform people once that have begun to participate in projects, but this could not be recorded in our review. A surprisingly large proportion of projects used mail as a route to allow people to be involved (21%); we suspect that this route would be used by a very small proportion of participants in most projects, but it does enable people without computer access to take part. A surprisingly large proportion of projects also used personal contact (12%) to involve people, although there appears to be a culture of local volunteering in the USA which makes this feasible within the context of local site monitoring.

Support. Most projects provide supporting material online (72%) in the form of instruction sheets or protocols, and this is especially associated with mass participation projects (dimension 1 of the MFA). In contrast, 24% of projects provide personal training, e.g. attendance at training days, some of which is in advance of taking part (12%). Both of these are associated with local projects (the other extreme of dimension 1 of the MFA). Few projects make use of the ability to provide online media (9%), such as videos explain methods, which should be considered more widely, especially for mass participation projects.

Targeting. 21% of project specifically targeted school children, by providing resources for children or teachers. This was associated with the second dimension of the MFA, so projects targeting school children tended to be more thorough. Potentially, the recruitment of school children to a project permits projects to demand more (since the children will be supervised during a lesson) and invest more (since the teachers will not participate if the activity is not well resourced). The same proportion of projects (21%) targeted people who had prior relevant experience, .e.g. the ability to identify birds before taking part. These projects would not be successful without this reasonably interested core of people to participate, yet many such projects (e.g. bird monitoring projects) produce high-profile outputs, e.g. inputting to national bioindicator trends.

Data accessibility, availability and quality

The availability of the data to view is strongly associated with the degree of mass participation (dimension 1 in the MFA results), with local projects being less likely to provide data to view. For a substantial minority of projects (20%) the data are not available to view, and another minority provide the data only summarised in report form (9%), usually after the data has been collected, collated and analysed. It may be that participants to such projects receive feedback in other ways, or that the projects are more local in scope so people have strong motivations to participate. However 35% provide the full resolution data (which is often straightforward if the data can be plotted on a map), while 36% of projects provide a summary of the data (which may have been a map with the data aggregated at a suitable scale). Our review suggests is that maps are very often the only form of data visualisation despite the usefulness of graphs to summarise data. For just under half of projects (42%) data is dynamically updated, so permitting people to see the value of the data they have submitted; which is associated with mass participation projects and we believe this is because this is a strong motivation for continuing to take part in the project. The availability of the data to download is much more limited; 18% of projects permit the full resolution dataset to be downloaded, and 20% permit a summary of the data to be downloaded. Making the data available to download in an understandable form requires excellent database management and permits the re-use of the data, however it does run the risk of removing control from the project team, e.g. for analysis or reporting results. If the data were available to download, it was almost always possible to view the full data. In these cases, it was often that the two processes of viewing and downloading were synonymous. Many projects that had ceased collecting data did not provide data to download or view, but did provide a final report, summarising and interpreting the results. There is clearly scope for increased interactivity by volunteers with the data collated through citizen science.

In summary the semi-systematic review revealed:

- The variation in extant citizen science projects can be explained on two main axes, according to their degree of mass participation and their thoroughness. This allowed extant projects to be classified into four main groups, which we call: simple local projects, thorough local projects, simple mass participation projects and thorough mass participation projects.
- That some types of scientific endeavour that share the features of citizen science do not ‘brand’ themselves as such, thus making it challenging for the widest possible sharing of good practise.

- Although citizen science projects that receive the highest profile are national or multinational in scope, many citizen science projects are local in scale.
- Almost all citizen science projects that we revealed in our search are contributory (established by professionals, and inviting people to contribute data). Very few projects appeared to have involved the public in their establishment.
- UK projects were disproportionately unlikely to have and require high investment (in terms of provision of support and clarity of aims and complexity of the task and time needed), according to our classification, in comparison to citizen science in the US.
- Many citizen science projects are high profile, and so we believe that more opportunities could be made of partnering with commercial organisations for overall scientific benefit.
- For projects focussed on the marine/shore environment, there appears to be a paucity of thorough mass participation projects, indicating a potential opportunity for growth in this area.
- That the effort required by participants tended to be matched by the investment made by the project team (in providing context and clarity of aims).
- That a substantial minority of projects did not state their aims clearly.
- That the requirement for relatively long visits, repeat visits, and visits to sites that are allocated in advance are strongly associated and there is potential to reduce the volunteer investment (and so possibly increasing involvement) by cutting across these parameters, for example utilising short repeat visits to allocated sites.

3.0 Citizen science case studies

3.1 Approach to case studies

Detailed case studies of citizen science were used to provide additional information to align with the semi-systematic review and provide in-depth examples of current practice across a range of approaches. Thirty-three citizen science initiatives were selected from the semi-systematic review using a stratified approach to ensure that the case studies represented the breadth and diversity of citizen science. For example, the case studies were selected to ensure appropriate representation across biodiversity and environmental-based citizen science. Additionally we aimed to include citizen science with coverage at various spatial scales from the county to global level but with an emphasis on UK. One additional case study, Galaxy Zoo, was invited. Galaxy Zoo does not collate biodiversity or environmental-based observations but it has such a high profile and has been expanded to incorporate a suite of citizen science initiatives through the website Zooniverse (www.zooniverse.org/projects) and so was deemed a good example to reflect on. Therefore, a total of 35 case studies were selected. People with a lead role in the selected citizen science initiatives were invited to contribute through completion of a case study template (Figure 2). An example was provided (OPAL Bug Counts) and all queries were addressed by e-mail. A total of 30 case studies were returned completed (Appendix 2).

Figure 2. Case study template provide to data providers invited to contribute a case study.

Project title:
Author:
Primary aim of the project:
Type of project (e.g. Contributory = people submit data to an institutionally-controlled project; collaborative = people invited by an institution to create a project; co-created = people and institution work together from start for benefit of a community):
Brief introduction (100 words):
Start date:
Current status (e.g. active and ongoing or complete):
Geographic scope:
Routes to involvement (e.g. website, app, workshops etc):
Type of data collated (presence/absence, abundance, soil temperature etc):
Data storage and availability (e.g. available through a web portal such as the NBN Gateway):
Quality assurance (e.g. none, data validated by expert etc):
Training involved:
Partners involved:
Number of participants:
Successes (250 words):
Lessons Learnt (250 words):
Cost:
Policy relevance (e.g. indicators, evidence for policy etc):
Project outputs (e.g. peer-reviewed papers, newsletters etc):

3.2 Summary of results

In total 34 case studies were invited and 30 were completed (Table 2). The case studies are provided in full (minus cost information) within Appendix 2.

Table 2. The 30 citizen science initiatives which contributed case studies including type of project (contributory or co-created), start date, scope, observation, number of participants and records. *indicates that the primary aim was not to generate records. **indicates collation of records is incomplete and so data unavailable.

	Type	Start date	Scope	Observations	Participants	Records
Audubon Pennsylvania Bird Habitat Recognition Program	Contributory	2009	Pennsylvania	Environment and various	521*	
Big Garden Bird Watch	Contributory	1979	UK	Birds	592475	100 000000
Common Bird Monitoring in Bulgaria	Contributory	2004	Bulgaria	Birds	125**	
Common Bird Monitoring in Luxembourg	Contributory	2010	Luxembourg	Birds	37	31000
Conker Tree Science	Contributory	2010	UK	Moths and parasites	5000	10000
Corfe Mullen BioBlitz	Co-created	2011	Dorset	Various	100	762
eBird	Contributory	2002	Global	Birds	25000	100000000
Galaxy Zoo	Contributory	2007	Global	Galaxy classification	300000	200000000
Garden BioBlitz	Co-created	2012	UK	Various	50	1698
Great Eggcase Hunt	Contributory	2003	UK	Sharks	800	31500
iSpot	Co-created	2009	UK	Various	18830*	
Weather Observations Website	Contributory	2011	Global	Weather	2000	38000000
*my*Soil	Contributory	2012	UK	Soil properties	5730*	368
National Bat Monitoring Programme	Contributory	1996	UK	Bats	2299	47947
Old Weather	Contributory	2010	Global	Weather	16400	1600000
OPAL Bugs Count	Contributory	2011	UK	Various	19500	670000
OPAL Network	Contributory	2007	England	Various	500000*	42500
OPAL Soil Survey	Contributory	2009	England	Earthworms and soil properties	4196	6000
Open Farm Sunday Pollinator Survey	Co-created	2012	UK	Insects	556	15046
Predatory Bird Monitoring Scheme	Contributory	1962	UK	Contaminant concentrations in birds		
Recording Invasive Species Count	Contributory	2010	UK	Various	633	1166
Rothamsted Light Trap Network	Contributory	1964	UK	Moths	84	
Scotland Counts	Co-created	2011	Scotland	Various	1000*	
Shore Thing	Contributory	2006	UK	Various	3000	35074
UK Butterfly Monitoring Scheme	Contributory	1976	UK	Butterflies	1500	4540152
UK Ladybird Survey	Contributory	1971	UK	Ladybirds	11000	110000
UK Mammal Atlas	Contributory	2011	UK	Mammals	3000**	
Wetland Bird Monitoring Scheme	Contributory	1993	UK	Birds	2000	121613
Wider Countryside Butterfly Survey	Contributory	2009	UK	Various	1200	268794
Wildflowers Count survey	Contributory	2010	UK	Plants	800**	
Mean					**56976**	**14953039**

Table 3. Overview of the 30 case studies by selected parameters.

Parameter	Number	Representation in the 30 case studies	Representation in the 234 projects in the semi-systematic review
UK case studies (including regional examples)	23	76%	22%
Marine case studies	3	10%	14%
Terrestrial case studies	26	87%	64%
Freshwater case studies	1	3%	16%
Case studies with data validation or verification	22	73%	20%*
Contributory projects	25	83%	92%
Case studies with policy relevance	11	37%	-
Biodiversity case studies	25	83%	79%
Weather and soil case studies	7	23%	21%
Case studies exclusively on birds	6	20%	-
Case studies including more than one group of organisms	10	33%	-
Mean number of participants	56976 (range 37 to 592475)		-
Mean number of observations	14953039 (range 520 to 300000000)		-
Mean duration to date	11 years		13 years**

- = the data were not assessed in the semi-systematic review

* = in the semi-systematic review data validation/verification was difficult to assess and so this is an under-estimate of the true figure.

**= it was only possible to assess the start date for half of the projects in the semi-systematic review.

Geographic scope

Most of the case studies were UK relevant (19 case studies) with a small number of additional case studies relevant at either regional or local scale within the UK (4 case studies). Four of the case studies were of global scope. The remainder were from US and European countries. The variety of projects demonstrates the scalability of citizen science to meet needs with relevance of different spatial scales.

Scope of observations

Of the 30 case studies, 25 were biodiversity-focussed. This high proportion (83%) is representative of current citizen science activity and supports the findings of the semi-systematic review, reflecting the relative paucity of environmental citizen science projects. The success of citizen science projects collating information on birds is evident from the selection of case studies. There are also a number of projects (10) that collate information for more than one group of organism. This, coupled with the number of projects that gather multiple types of environmental observation (species, weather and habitat) clearly demonstrates the desire to maximise the efforts of volunteers in gathering relevant information. It further highlights the need to ensure all data collated are accessible and not just the core focus. For example, the UK Butterfly Monitoring Scheme focuses on monitoring butterfly diversity and abundance but also collates high quality weather data. Effective crowd-sourcing of weather data could provide a rich resource by combining data from many relevant sources, indeed oldWeather has highlighted the potential for such an approach. The mean duration of projects was 11 years and the number of participants and observations collated was often very high. Although we mostly invited well-known (hence well-established and successful) projects to contribute case studies, it does highlight the potential longevity and success of citizen science projects.

Ornithological citizen science, as already stated, has a long and rich history. It is encouraging to see the evidence of knowledge transfer across projects particularly those focusing on birds. For example, Common Bird Monitoring in Bulgaria was supported by the Royal Society for the Protection of Birds (RSPB) building on the success of their mass participation initiatives. Many of the case studies recognise the need to share best practice across the participating community. eBird has enabled this both virtually, through “meta” contribution activities, and face-to-face, through local networks involving well-known and highly skilled birders who manage projects and train new recruits. Similarly Galaxy Zoo, galaxy classification through contributory citizen science, encourages participants to communicate through a custom-built (and open source) ‘Talk’ object-orientated discussion system. *my*Soil provides the facility for users to share knowledge and information on soil through a smartphone app.

Most of the case studies involved the contribution of observations, indeed only five of the examples did not have data gathering as the primary aim. In most cases the observations constituted data collated in the field or virtually (such as oldWeather and Galaxy Zoo), however two schemes are notable exceptions: the Predatory Bird Monitoring Scheme and Rothamsted Insect Survey (RIS) Light Trap Network. The Predatory Bird Monitoring Scheme involves the submission of dead predatory birds for assessment of contaminant concentrations in the tissues and eggs coupled with macroscopic observations from examination of the bird. The RIS Light Trap Network uses a combination of approaches engaging some volunteers in species identification while offering others the option of submitting physical specimens. The Bat Conservation Trust is developing an initiative that would involve contribution of physical samples (bat faeces) for DNA analysis leading to species identification. Clearly there is considerable potential for development of projects that take such an approach. The longevity and success of both the Predatory Bird Monitoring Scheme and RIS Light Trap Network are testament to this.

Design of citizen science

The dominance of contributory projects matches with the findings of the semi-systematic review and highlights the success of mass participation projects. The Big Garden Birdwatch is considered to be one of the largest biodiversity monitoring projects worldwide and has accrued a database with more than 100 million records. While the data collated include a degree of noise, the volume of records compensates for this and trends in bird populations reflect those from rigorous monitoring schemes such as the Breeding Bird Survey. The data from the Big Garden Birdwatch contribute to the Defra "Town and Garden" wild bird indicator.

Other mass participation projects such as the UK Ladybird Survey achieve smaller data holdings (approximately 110,000 records) than the Big Garden Birdwatch but the data are verified and validated allowing confidence in data. However, many of the small to medium-sized mass participation projects are subject to bias in the intensity of spatial sampling (some regions have better coverage of participants than others, hence the recording intensity varies). New statistical techniques overcome such problems and allow rigorous interpretation of these data with respect to population trends (Roy *et al.*, 2012a).

Engagement

Governance and progression are seen as critical to engaging and sustaining the involvement of volunteers (Grove-White *et al.*, 2007). Evidence of governance by volunteer participants is evident in a few of the case studies, particularly eBird and the BioBlitz examples, but could be more widely and imaginatively built into citizen science. Progression is apparent in many of the case studies either explicitly (iSpot badges, eBird project leaders) or implicitly (feedback on identification is provided, for example the UK Ladybird Survey).

Training is a common method of ensuring the skills progression of new recruits. It also gives people confidence in taking part, especially if protocols are relatively demanding or complex, and can enhance the reliability of the records received. Many of the case studies described the training methods used and these are rich and varied ranging from formal training sessions to carefully constructed survey packs and other downloadable materials. The Open Farm Sunday Pollinator Survey included training both for the ecologists mentoring participants during the survey and for the participants during the survey. The OPAL Bugs Count project provided support through a mobile phone app, and survey packs both for participants and group leaders. The Great Eggcase Hunt provides training both for accurate data entry and species identification. The Wetland Bird Survey takes a flexible approach to training whereby formal sessions are provided for recruits who do not already possess bird identification skills. The Shore Thing provides training designed for the different sections of their volunteer community (participants, teachers and ecologists). The necessity to provide regional training is acknowledged by the UK Butterfly Monitoring Scheme (UKBMS) which facilitates training through local branches of Butterfly Conservation. The UK BMS also offer mentoring "on the job" by allowing new recruits to shadow more experienced volunteers. The UK Ladybird Survey, like many national recording schemes, runs annual identification workshop mainly through the British Entomological and Natural History Society. Undoubtedly the most widely used method of enabling skills progression is the provision of on-line resources. There is certainly scope to share knowledge on best practice in citizen science, particularly guidance on the most effective means of delivering on-line training and resources. Of course training and support needs to be fit-for-purpose, so simple, mass participation projects rarely need the investment in training described in many of the case studies.

The importance of feedback to volunteers is echoed throughout all the case studies. Audubon Pennsylvania Bird Habitat Recognition Program, which aims to increase resources for wildlife by engaging people in ecological restoration of their properties, highlights that "*constant communication is key to maintaining interest*". Similarly the Common Bird Monitoring Programme is keen to improve communication to various audiences including participants and policy-makers, recognising importance of effective communication for recruitment and retention of volunteers. eBird highlight the importance of timely feedback and states "*the more instantaneously feedback can be provided, the more motivating it is*." Feedback from participants is also important and a first step in providing volunteers with an opportunity for governance. The Met Office Weather Observations Website offers the opportunity for participants to provide feedback on problems experienced with the website and this allows rapid resolution. The Wildflowers Count Survey found feedback from participants useful in improving the design of the project, particularly in enhancing ease of data entry and increasing flexibility of design to meet the diverse requirements of participants. The Wider Countryside Butterfly Survey acknowledges the importance of feedback to maintain enthusiasm and interest but also highlights the role of local co-ordinators in this regard. A number of the case studies (for example Wetland Bird Survey, UK BMS, National Bat Monitoring Programme, RIS Light Trap Network) describe the use of annual reports and newsletters distributed both as hard copies and as downloadable documents.

Communication is critical at all stages of citizen science. The UK Ladybird Survey benefitted from a full-time project officer on a short-term contract, after the launch of on-line recording in 2005, to promote the survey in diverse ways (from displays at agricultural shows to natural history talks and workshops alongside press releases). The UK Ladybird Survey has generated approximately 200 news items per annum since launching the on-line components in 2005 but also uses many other means of feedback including the publication of an atlas (Roy, Brown, Frost *et al.*, 2011) and Twitter. iSpot benefits from the Open University links with BBC natural history programmes but also uses Twitter actively.

Twitter (and other social media) is increasingly playing a role in citizen science. Many recording schemes and societies use Twitter to promote their activities to a wide audience. It enables rapid and succinct feedback to a wide audience. Additionally communities can be established around citizen science through Twitter. The Garden BioBlitz was derived through the dialogue using Twitter by a number of natural history enthusiasts. The Garden BioBlitiz team recognise the role of Twitter (also iSpot and Flickr) in providing real-time identification and rapid feedback to recorders which was believed to foster a community spirit amongst recorders and encouraged participation.

Data accessibility, availability and quality

Many of the citizen science projects explored in detail through the case studies either have existing smartphone apps or are in the process of developing them. However, many offer other routes to involvement and traditional data capture methods such as paper forms although the recognition that on-line data entry reduces errors and improves the rate of data capture is acknowledged.

Quality assurance varies across projects but to some degree was evident in all. Many of the case studies demonstrated aspirations to provide high quality data and have mechanisms in place (verification and validation) to achieve this. However, a few are keen to encourage participation by all and predict that mass participation will assist in reducing the significance of the errors. Of course, where errors are systematic then increased participation will not enhance accuracy. The use of filters to remove out of range (temporal and spatial) records is common. In biological monitoring, where the output is a distribution atlas, then a very conservative approach is adopted, where records for new areas need substantial scrutiny on a case by case basis before being accepted, although this approach is exceptional in citizen science.

Skilled experts are commonly engaged to assist in verification (particularly for biodiversity data in which a photograph is submitted). A number of the case studies involve such verification mechanisms (such as UK Mammal Atlas, UK Ladybird Survey, RISC). Additionally mentoring is commonly used in citizen science. The support provided by national schemes and societies in mentoring new recruits through workshops, field excursions and by confirming identification of species is exemplary. The Open Farm Sunday Pollinator Survey was undertaken by people visiting farms but in most cases they worked alongside skilled ecologists who could assist. The Shore Thing Project also includes support from an ecologist within the surveys. The UK Butterfly Monitoring Scheme provides new recruits with a local experienced contact for mentoring and training. The Wetland Bird Survey recruits participants who have known expertise. In some cases citizen science data can also be validated against systematically collected data or models and this is embedded within some of the large projects (such as eBird).

OPAL included on-line tests within their project design and also observed participants undertaking surveys to quantify error rates and identify common mistakes. Implementing methods of progression and ways in which volunteers can express their confidence and certainty of the data they provide are also used (for example, iSpot) but could be more widely implemented.

Most of the case studies describe methods of data storage involving in-house databases but the use of Indicia (web-based database accessible by a designated community) is increasing. The willingness to share data was evident across the case studies and many of the UK examples use the NBN Gateway as a method of increasing accessibility to their data holdings. A few display data as summaries with interpretation through their project website but the data is often available on request. eBird data are freely downloadable from the website but are also part of the Avian Knowledge Network (AKN) which integrates observational data across the northern hemisphere. The AKN ensures that data is shared globally through the Global Biodiversity Information Facility (GBIF). The NBN Gateway is also a major data provider to GBIF. The Data Archive for Seabed Species (DASSH) is an initiative of the Marine Biological Association (MBA) and provides a mechanism for sharing marine data (The Great Eggcase Hunt and The Shore Thing Project) and formatting for upload to the NBN Gateway. The BRC (in conjunction with the national schemes and societies) and BTO databases provide similar services for non-marine data. WOW stores data on the Google cloud platform allowing users to access their own data and control whether other members of the community can have access to download their data.

Utility of citizen science

One-third of the projects were deemed to have some defined policy relevance (usually contributing to biodiversity indicators). Interestingly these projects all incurred annual running costs of between £70K and £150K which equates to a small proportion of the volunteer in-kind contribution, indeed volunteer observers for biodiversity surveillance were estimated to contribute time in-kind worth more than £20 million during 2007–08 (http://www.jncc.gov.uk/page-3721). Perhaps the greatest barrier to the uptake of citizen science, both participation and utility, is concerns over the quality of data. The willingness of people to provide data can be limited by their lack of confidence in the quality of the data they collect and hence concern that they may adversely affect the project. Data-users may be cautious in their inclusion of data collated through citizen science because of concerns with respect to data quality and, hence, trust in the results and interpretation. However, data quality issues are not unique to citizen science and large sample sizes can increase precision (Hochachka *et al.*, 2012, Gardiner *et al.*, In press, Crall, Newman, Stohlgren *et al.*, 2011, Bonney *et al.*, 2009b, Shirk, Ballard, Wilderman *et al.*). Issues should be addressed on a case-by-case basis using advanced statistical methods, biological insight and acceptance that data may be unsuitable for one question but adequate for another (Dickinson *et al.*, 2010). As for any research project, understanding the quality of the dataset generated is critical and the constituent data can then be handled accordingly. Of course, this can conflict with the increased desire to see the re-use and sharing of data, in order to make the most of it.

A commonly held view is that the skills of participants in citizen science are inferior to those of professional scientists (Grove-White *et al.*, 2007). We believe that this is a misconception. Quality assurance for citizen science monitoring of water quality is locally assured, demonstrating that sampling protocols and training meet legislative requirements (Bloch, 1999). Amateur biological recording experts are highly skilled individuals even though they are not 'professional'. Also mass participation projects usually select tasks which can be accurately performed by unskilled participants with appropriate instructions, ensuring good data quality, for example, projects such as Conker Tree Science (http://www.ourweboflife.org.uk/) and the OPAL Soil and Earthworm Survey (http://www.opalexplorenature.org/soilsurvey). In contrast, new recruits to natural history recording often need mentoring, either virtually (through initiatives such as iSpot or through a specific forum such as the Bees Wasps and Ants Recording Society, British Myriapod and Isopod Group or Dipterist Forum) or through field meetings and other face-to-face contact, to increase their skills. Many US projects that have a local focus (catchment water monitoring or monitoring invasive non-native species on national parks) often provide, and sometimes require, training before volunteers can take part in the project.

Many studies have documented "learner" or "first year" effects (Schmeller, Henry, Julliard *et al.*, 2009, Gardiner *et al.*, In press) and others have highlighted the importance of progression as a motivation to participants (Grove-White *et al.*, 2007). However, such biases are not insurmountable and the quality of citizen science data is greatly increased by a number of straightforward approaches. Mentoring and feedback from within the citizen science community ensures progression of recruits. For some, this development is an explicit aim of long-term projects, such as iSpot.

The National Biodiversity Network (NBN) provides useful guidance for data providers in relation to validation and verification whereby "*validation is the process of checking if something satisfies a certain criterion*" and "*verification is the confirmation or additional proof that something that was believed (some fact or hypothesis or theory) is correct*". Additionally the NBN in collaboration with its constituent partners had been instrumental in developing technical methods for improving data quality. While these are designed for biodiversity observations conceptually they are relevant to other environmental data. One example is the NBN record cleaner which aims to aid the process of data cleaning and ensure the quality of datasets through the application of verification rules (http://www.nbn.org.uk/Tools-Resources/Recording-Resources/NBN-Record-Cleaner/Creating-verification-rules.aspx) or smart filters (Bonter & Cooper, 2012). Validation rules, or smart filters, are essentially automated filters created to identify potentially erroneous observations (Bonter *et al.*, 2012).

There are a number of factors which can give rise to sampling bias. Intensive publicity following a press release, for example, can result in temporal bias whereas the geographic distribution of volunteers can result in spatial bias and incomplete spatial coverage: recording activity is uneven both in space and time. This is likely to be the main concern for environmental data (e.g. data from citizen-run weather stations), so requiring the structure in the data to be taken into account during analysis and subsequent interpretation. For biodiversity data a more taxing problem is the need to distinguish between cases where no data means a species' absence and where it means a species was present but undetected. One approach to overcome both spatial and temporal sampling bias is to require volunteers to provide lists of species recorded, often with their recorded abundance and under standardised sampling approaches, such as transects methods used by the UK Butterfly Monitoring Scheme or the BTO Breeding Bird Survey. These require high commitment from volunteers. Statistical approaches can be applied to take account of the detectability of species (Zuckerberg, Bonter, Hochachka *et al.*, 2011), and so provide estimates of changes in 'occupancy', i.e. the probability of a species being present, from which changes in the state of species can be inferred (van Strien, Termaat, Groenendijk *et al.*, 2010). Even more challenging are the extensive occurrence records, such as those collated by the Biological Records Centre and made available via the National Biodiversity Network (NBN) Gateway (http://data.nbn.org.uk/).

The records collated by the volunteer schemes and societies are extremely valuable because they are often the only sources of high quality information on a wide variety of taxa over a large-scale and long-term. Therefore, there is considerable potential to quantitatively explore changes in the distribution of species using these datasets. However, not only is recorder effort unstructured and patchy in space and time, but the intensity of recorder effort at any point in space and time is not known (Hill, 2011). The desire to make best use of these extensive datasets has lead to a proliferation of methods for assessing trends in species' distributions ('range change'). These methods vary in sophistication and in the assumptions they make about the data from relative change index (Telfer, Preston & Rothery, 2002), local frequency scaling (Hill, 2011) to occupancy modelling (van Strien *et al.*, 2010). Detailed descriptions of these approaches are beyond the scope of the report but more information is available (Botts, Erasmus & Alexander, 2012, Hochachka *et al.*, 2012). Overall, statisticians have been instrumental in adopting new and more rigorous methods of data analysis to increase understanding of sources of variation inherent in all environmental data, and investment into research in this area should be continued.

In summary the case studies revealed:

- A strong alignment on the values, design and implementation of citizen science with end-use.
- That most of the citizen science represented through the case studies involved a contributory approach and generally of observations collated in the field or virtually.
- The cost of citizen science that directly informed policy, for example through development of indicators, was in the region of £70K to £150K per annum. Indeed all citizen science incurs some cost particularly in the initial phases. A diversity of citizen science both in terms of geographic scope and range of observations.
- The importance of feedback and engagement as a component of citizen science. The many ways in which this is achieved is fascinating and further demonstrates the value of sharing good practice. Social media is increasingly being used as a means of providing rapid and interactive feedback. Equally face-to-face mentoring is commonly used and an effective method of maintaining motivation and engagement of volunteers.
- That mechanisms are often in place and able to meet users aspirations to provide high quality, accessible (verification and validation) data.
- The utility of the data to help inform policy and particularly our understanding of the changing environment.

Additional specific points included:

- Methods for enhancing data quality are nearly always included with the design.
- Training provides a valuable way of improving data quality while ensuring progression of volunteers.
- The NBN Gateway is widely used for sharing data.
- Citizen science is not free and even the most straightforward contributory citizen science involves costs for basic resources.

- Social media (such as Twitter) provide exciting opportunities for promoting citizen science and providing feedback.
- Publicity and promotion are critical to the uptake of citizen science.

4.0 Policy-needs based on structured interviews with citizen science data users

4.1 Overview of the interaction between policy and citizen science

A number of recent policy documents and initiatives highlight the critical role of volunteers in environmental monitoring. Citizen science is not always explicitly mentioned but the desire to increase engagement and participation to underpin environmental policy is evident. The Water Framework Directive acknowledges the crucial role of citizens and citizens' groups for two main purposes. First, decisions on the most appropriate measures to achieve the objectives in the river basin management plan will involve balancing the interests of various groups. Second, it is anticipated that transparency in the establishment of specific objectives, measures and standards will enhance implementation and governance of citizens in environmental protection. The Sixth Environment Action Programme (EAP, "Environment 2010: Our future, Our Choice") includes the Thematic Strategy on Air Pollution and Clean Air for Europe (CAFE). Over the next ten years there will be a focus on implementation of air quality standards and coherency of all air legislation and related policy initiatives (http://ec.europa.eu/environment/air/quality/index.htm). The appeal of air and water quality to citizen science is evident from an innovative project launched by the European Environment Agency in partnership with Microsoft. Eye on Earth (http://watch.eyeonearth.org/) is a two-way communication platform on the environment which brings together scientific information with feedback and observations from people across Europe. It currently includes information on the water (>22 000 bathing sites) and air quality (>1000 monitoring stations) throughout Europe. Eye on Earth is anticipated to expand to include information on other environmental themes with the ambition to become a global observatory for environmental changes including ground level ozone and other forms of air pollution, oil spills, biodiversity, and coastal erosion.

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The Natural Environment White Paper, "*The Natural Choice: securing the value of nature*", was published on 7 June 2011 and a number of implementation updates have followed (http://archive.defra.gov.uk/environment/natural/documents/newp-imp-update-20120717.pdf). The White Paper builds on the UK National Ecosystem Assessment (June 2011), which assessed the social and economic benefits derived from the natural environment, and provides an example of the way in which policy documents are highlighting the role of volunteers in environmental monitoring. The White Paper highlights commitment to further investment in the development of the National Biodiversity Network (NBN) and the creation of a new fund for biodiversity recording in the voluntary sector. However, recognition that the provision of evidence from such monitoring programmes is not cost-free is critical. Environmental monitoring relies on long-term support in terms of volunteer liaison, data handling, quality assurance, publication and statistical support for measuring trends. The White Paper highlights that people in the UK are motivated to protect nature. This notion is also supported at a European-level through the SEBI **(**Streamlining European 2010 Biodiversity Indicators) "public awareness indicator" which reported that over two-thirds of EU citizens report personally making efforts to help preserve nature.
The Pan-European SEBI initiative was launched in 2005. SEBI aims to develop a European set of biodiversity indicators to assess and inform European and global biodiversity targets. SEBI links the global framework, set by the

Convention on Biological Diversity (CBD), with regional and national indicator initiatives. Many of the headline indicators rely entirely on the availability of monitoring data and particularly datasets on biodiversity developed by volunteer naturalists (Levrel *et al.*, 2010). The participation of volunteers in the development of these monitoring schemes is not only beneficial in collating large-scale and long-term datasets but also results in other advantages including improvement of the public's knowledge of biodiversity (Cooper *et al.*, 2007), support of public debates and reduction in the costs of biodiversity monitoring (Levrel *et al.*, 2010).

The European Biodiversity Research Strategy 2010-2020, adopted through the European Platform for Biodiversity Research Strategy (EPBRS) in April 2010, documents the need to "*develop links between science and public engagement networks like natural history museums, science centres and citizen science programmes*" (www.epbrs.org/PDF/EPBRS_StrategyBDResearch_May2010.pdf). The overall aim of the strategy is to "*Generate and share the knowledge necessary to bring human societies into a sustainable and mutually beneficial relationship with the living world*" which aligns with the motives of citizen science. The EU 2020 biodiversity strategy was in response to the CBD mandate through the establishment of biodiversity objectives and global commitments aligned to the Aichi Biodiversity targets.

In 2010 the CBD conference of the parties adopted the Aichi Biodiversity targets through a relevant overarching framework on biodiversity contributing to the Millennium Development Goals (http://www.un.org/millenniumgoals/). Aichi Target 1 explicitly states "*By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably*". Citizen science has a role in such awareness raising but also in providing evidence to evaluate the implementation of actions to address the Aichi targets. For example, the European Strategy on invasive alien species (IAS) is developing partly in response to Aichi Target 9 "*By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment*." The role of citizen science in ensuring early warning and rapid response of IAS has been recognised. Indeed the GB Non-Native Species Information Portal (GB-NNSIP) encourages people to submit records of species of concern to an on-line alert system. The killer shrimp *Dikerogammerus villosus* was detected in England and Wales in 2010. The critical role of anglers, boat owners and other recreational users of water bodies in surveillance to limit the spread of this species has been recognised by the Non-Native Species Secretariat. Additionally the volunteer recording community has provided much of the information within the GB-NNSIP (Roy, Bacon, Beckmann *et al.*, 2012b).

Volunteering has been prioritised within the UK government's policy agenda for many years (O'Brien *et al.*, 2008). In 2006 a commission on the Future of Volunteering was established to develop a long-term vision for volunteering in England. The British Government, Scottish Government, Welsh Government and Northern Ireland Executive have all committed funds to build capacity within the voluntary sector, in general, and raise awareness of the important role of volunteers by making people aware of the opportunities and encouraging more people to volunteer. There have been concerns that end-users, including policy-makers, have not recognised the value of citizen science for monitoring the environment and providing evidence to underpin policy (Grove-White *et al.*, 2007). Indeed, there is perception that information collated through citizen science is of insufficient quality for high level use (Grove-White *et al.*, 2007). However, over the last few years there have been a number of publications that demonstrate the utility of citizen science for policy and other purposes. UK examples are heavily biased towards structured monitoring programmes such as the UK Butterfly Monitoring Scheme, UK Breeding Bird Survey and National Bat Monitoring Programme (Brereton, Roy, Middlebrook *et al.*, 2011, Fox, Randle, Hill *et al.*, 2011, Fox, Warren, Brereton *et al.*, 2011, Battersby & Greenwood, 2004, Gregory, Noble & Custance, 2004, Davey, Vickery, Boatman *et al.*, 2010, Butler, Brooks, Feber *et al.*, 2009).

4.2 Approach to end-user interviews

Interviews of defined end-users (mainly government agencies and government departments) provided an opportunity to add further context to the information collated through the semi-systematic review and case studies. Eighteen citizen science data users or potential users were identified through consultation with the UK-EOF steering group. Interviews were carried out from the end of June to early July 2012 and followed a standard format. Initially, the project was introduced followed by an overview of the purpose of the interview and a description of how it will link with the semi-systematic review. This was followed by discussion around 16 questions which were developed to align with the semi-systematic review (Appendix 3).

Sequence of questions used in the structured interviews with citizen science data users

1. Can you give a brief overview of the current priorities or needs for environmental observation data from your organisation's perspective (all data – not just focussing on citizen science)? (from a policy perspective – to support delivery, implementation or assessment)
2. Do you see a role for citizen science data in the development or delivery of UK environmental policy?
3. How would you envisage using citizen science? Precise data collecting, gathering trends, keeping an eye out for new arrivals, regular repeat monitoring?
4. What would your aims be? What would you use the data for?
5. Do you currently run or fund citizen science? If no, do you think your organisation might in future?
6. How would you expect to see projects created? (Collaborative, contributory, co-created)
7. What would your geographic scope be? When running the project, how much freedom could you give participants in selecting their own sites, or for your needs would they need to be pre-selected?
8. What routes to involvement would you anticipate providing? (e.g. website, app)
9. How would you seek to provide support?
10. Would you seek to specifically engage school children? Would you need to engage people who are already experienced? Would you seek to engage with anyone?
11. For the sort of citizen science and engagement you might seek, how much effort do you think you would require from participants? Would it be necessary to repeatedly visit sites?
12. Would you anticipate people require specific equipment?

13. What sort of data would be useful to you?
14. Would you consider quality assurance of your data? Would it be critical?
15. Would you seek to make the data publicly available? Would there be access restrictions?
16. What would be your primary motivation (or need) for the data?

The interview was closed after inviting the interviewee to provide any additional information and then briefly reaffirming uses of the data and confidentiality.

4.3 Summary of results

Interestingly, despite the unanimous recognition by the organisations interviewed of the role of citizen science in their work, only a small minority currently fund or use citizen science data. The few end users of citizen science mainly rely on the systematic monitoring programmes even though this represents only a small fraction of the citizen science data available. It is clearly desirable to ensure that citizen science has utility, for example providing evidence to underpin policy or addressing scientific questions, while retaining relevance and interest to the volunteer participants. The Scottish Government fund citizen science through competitive science engagement grants programme which currently funds Scotland Counts (BTCV training volunteers to biological record whilst doing conservation work) and has non-competitive funding available for schools through schemes such as Generation Science.

Economic perspectives

The economic benefits are perhaps the most notable and have been quantified through a number of studies. For example, it is estimated that the monetary value to the French administration of the volunteer activity which enables Implementation of the indicator "*Trends in the abundance and distribution of selected species*" is between 678, 523 and 4,415,251 euros per year (Levrel *et al.*, 2010). In the UK the annual £88 million spend on environmental monitoring underpins up to £6000 million of benefits to the UK economy (Slater, Mole & Waring, 2006, Mackechnie *et al.*, 2011).

The EuMon project conducted the first large-scale evaluation of monitoring practices in Europe through an on-line questionnaire documenting 395 monitoring schemes for species, which represents a total annual cost of about €4 million, involving more than 46,000 persons devoting over 148,000 person-days/year to biodiversity-monitoring activities (Schmeller *et al.*, 2009). The results suggest that the overall sampling effort of a scheme is linked to the proportion of volunteers involved in that scheme. Precision is shown to be a function of the number of monitored sites and the number of sites is maximized by volunteer involvement. Therefore, the results of this study do not support the common belief that volunteer-based schemes are too noisy to be informative. Indeed volunteer-based schemes provide relatively reliable data, with state-of-the-art survey designs or data-analysis methods, and consequently can yield unbiased results (Schmeller *et al.*, 2009). Quality of data collected by volunteers is more likely determined by survey design, analytical methods and communication skills within the schemes rather than by volunteer involvement per se. As an example a recent study exploring the reliability and cost-effectiveness of citizen science for assessing trends in diversity of ladybirds in the UK and USA highlighted the benefits of scientists working with volunteers (Gardiner *et al.*, In press). The involvement of volunteers significantly reduced costs (from $40,460 to $14,148) and increased the temporal and spatial scales at which we can understand ladybird declines.

Design of citizen science

The need for citizen science following a diversity of models was seen as important. However, organisations acknowledged that contributory projects allow mass participation and are easier to run. One interviewee stressed the need for a top-down approach yielding systematic protocols but all others recognised the benefits of including the volunteer community in design and delivery of projects. However, funding provision would allow more ambitious projects to be designed, for example following a co-created model. It was widely recognised that new technology (specified as apps, websites and sensors) offer considerable potential but that more traditional routes of engagement (personal and virtual mentoring, workshops and identification keys) remain highly relevant.

It was interesting to note that, while all organisations recognised a critical role of citizen science to meet the growing demands of environmental monitoring, some did not consider citizen science as a part of their core remit although they would like to use the data. Indeed very few bodies fund citizen science directly - some fund through intermediaries and others rely entirely on the initiative of the others to direct projects. In many cases other organisations are likely to be better placed to recruit and manage volunteers on behalf of the funding body. Nevertheless there does appear to be a paradox whereby some organisations have prescriptive needs for citizen science data but rely entirely on good-will of others to develop and implement the projects.

It was recognised that the outputs from citizen science depend on the support provided. Citizen science is not cost free. From the case studies it is evident that the large-scale projects that provide evidence for policy are generally funded (approximately £130k to £150k per annum). Better use could be made of a greater range of projects but skilled statistical analysis and interpretation is required. Additionally some projects require specialist equipment such as met stations, phosphate analysis kits, GPS. Such projects are likely to appeal widely to volunteers and citizen science should be ambitious in such regards.

Data accessibility, availability and quality

The need for national and regional data aligns well with the current landscape of citizen science initiatives in the UK. However, understanding of data quality remains a critical constraint at all scales. A minority of the interviewees viewed citizen science data quality as a major constraint to data use. One explained that they were "*sceptical about value of data*". However, a more common view was that understanding data quality allows for more comprehensive use than is currently the case. Many organisations took a pragmatic view, recognising that quality is important but that what is required varies depending on the end use. They stressed that, for biodiversity data, the gains in spatial and temporal information can far outweigh any accuracy concerns. There are important gains to be made in engagement through citizen science regardless of data quality and as long as the level of quality is known then analyses can adjust for errors. One organisation stressed "*a single observation isn't critical, as interpretation will be* *based on whole dataset*". Another suggested that "*there is some science snobbery over the quality of data from volunteers and the sheer volume of data through mass participation will cancel errors out. More rigorous protocols would reduce error/variables and additionally volunteers should be invited to flag up any problems so data quality is known*." The Met Office WOW has a star system where participants rate their perception of the quality of their data, and the rest of the community can comment on the data quality within other sites. The Met Office then download a sub-set of these data for use and undertake further quality control procedures, mainly by comparing data to computer models.

There was general recognition that investment should be made into work on quality assurance, in part to convince some scientists and policy-makers of the utility of the data. Technology (for example iSpot, Indicia, iRecord and NBN Record Cleaner) can help with data quality and additionally there are modelling techniques available to assist in analysis of unconventional datasets. However, there is a lack of understanding around the level of uncertainty that policy data can cope with. Confidence limits and validation levels will vary with citizen science projects and should be documented alongside the data regardless of origin. There was a general desire to engage a diverse range of volunteers but many organisations highlighted the critical role of skilled volunteers and specifically the national schemes and societies. Indeed national taxonomic experts were described by a number of the interviewees as key to delivering quality assurance.

While all the organisations concurred that primary data should be available and accessible, it was also acknowledged that sometimes it was appropriate to make data publically available as a summary with interpretation (for example as a biodiversity indicator). It was widely stressed that citizen science should not be regarded as a cheap way to gather data. Although volunteer recording is cheaper than paying professionals the effort and support required (infrastructure, training, feedback, events, website etc) should not be underestimated. End-users are keen to move to comprehensive use of appropriate citizen science and would value sharing methods for doing so.
The interviews with the end users revealed that data availability to other users was very important. However, none of the end users mentioned a specific desire for data to be available to participants and other members of the public, yet the increase in crowd-sourced data use, e.g. 'mash-ups' combining several different datasets to reveal novel findings and created by members of the public, show that this could be an increasingly rewarding approach.

There is also a recognition by the organisations interviewed that citizen science does not just appeal to members of the public but industry is keen to get involved particularly if it can provide useful data while going about its usual work. One example is the gathering of meteorological data from GPS satellites and commercial aircraft. Commercial aircraft in particular provide data from places where weather stations couldn't be placed such as in the middle of oceans, and from the upper air, as opposed to ground level. Aircraft collect these data anyway for their own flight use, but the Met Office pay for (almost) real time transmission of data (approximately 42,000 observations per day). Future opportunities include assessing the possibilities of gathering meteorological data based on the quality of mobile phone signals and also from Air Traffic Control radar.

Utility of citizen science

The main requirement for data is to monitor change over large temporal and spatial scales. The demands of Biodiversity 2020 targets and need for evidence to underpin policy through various statutory indicators require such data. Mass participation citizen science is well placed to meet this need if protocols and technology are effectively used to manage quality. It is not surprising that all the organisations interviewed responded positively to the question “Do you see a role for environmental citizen science in supporting your work?” Indeed one government body commented that approximately 85% species-level biodiversity data that they use is generated by volunteers. However, they acknowledge the challenge of increasing the provision of habitat data through citizen science. It is apparent from our semi-systematic review and case studies that many citizen science initiatives gather habitat data alongside the focal biodiversity data. Mobilisation of this habitat data could prove fruitful. Additionally statutory bodies could outline their habitat data requirements and invite citizen science projects to respond by inclusion of appropriate methods. Evidence from various studies (Grove-White *et al.*, 2007, Koss, Miller, Wescott *et al.*, 2009) suggests that citizen science participants would welcome such monitoring that had obvious and clear-cut utility.

There are excellent examples of the utility of data collected by volunteers for example the production and use of national atlases. The compilation of national atlases using data collected by volunteers was pioneered In Britain and Ireland by the Botanical Society of the British Isles with the *Atlas of the British Flora* (Perring & Walters, 1962). Since then such atlases have been prepared for many groups of organisms. The initial emphasis on the collection of records from which distribution maps can be prepared has given way to the collection of detailed distributional data which can be put to multiple uses, including the preparation of maps. Atlas maps and the accompanying datasets have been put to numerous uses. They provide:

- summaries of the range of species in maps which are in turn often summarised in other works (including taxonomic accounts and field guides)
- the evidence required for drawing up Red Lists of threatened taxa
- a way of identifying gradients in diversity, ‘hotspots’ and ‘coldspots’
- data which can be used for fundamental scientific research into the properties of species’ distributions
- evidence which allows trends in the distribution of species to be identified; analysis of such trends (often by linking them to species’ traits) allows drivers of environmental change to be identified
- the UK and Irish contribution to atlases of the European biota.

The results of Atlas surveys have sometimes identified important declines in species frequencies which have then been taken up by policy makers. Citizen science in these cases has set the policy agenda rather than merely provided information required to further policy requirements defined elsewhere. Examples include the identification of the decline of pollinators (bumble bees) in midland England (Biesmeijer, Roberts, Reemer *et al.*, 2006) and early evidence for the decline in the birds of arable land (Gibbons, Reid & Chapman, 1993). In addition to national atlases, volunteers have often collected data for county atlases of many different groups in projects which have been contributory, collaborative, co-created or devised entirely by citizen scientists without professional involvement. The results from these initiatives provide valuable information of relevance to the national level but also for devising biodiversity policy regionally.

Cross-cutting reviews raise the profile of volunteer-collected-data to policy-makers, and have revealed further insights into the impacts of environmental change such as: biological impacts of climate change through northward of shifts of animal groups (Hickling, Roy, Hill *et al.*, 2005, Chen, Hill, Ohlemueller *et al.*, 2011); contemporary rates of population declines of bird, butterflies and plants that are higher than historical rates (Thomas, Telfer, Roy *et al.*, 2004); and threats to pollinator services through the parallel declines in pollinators and plants (Biesmeijer *et al.*, 2006). The impact of these studies is demonstrated by their very high level of citation by other researchers, with 192, 241 and 290 citations for (Hickling *et al.*, 2005, Chen *et al.*, 2011, Thomas *et al.*, 2004) respectively. The use of data (by scientists, policy-makers and other stakeholders) collated through citizen science will undoubtedly increase. However, a comprehensive review of current use within the UK would be timely.

Risks

A number of risks were highlighted during the interviews with data users. The loss of taxonomic expertise was raised as a concern and requires further investigation to assess the extent of this risk. The value of volunteer participants was appreciated while the potential to take advantage of the generosity of volunteers in providing time, enthusiasm and skills was also recognised particularly during financially constrained times. It was acknowledged that austerity and the notion of “Big Society” could impact adversely on citizen science because of insufficient investment in support and the supposition that citizen science is free leading to poor quality citizen science, public fatigue and confusion. Indeed the lack of a coherent and strategic direction for citizen science could result in inefficient and ineffective use of volunteer time. We believe a simple initiative such as an information portal bringing the citizen science community together, highlighting opportunities, sharing experiences and advertising the richness of data available would be tremendously advantageous.

In summary the structured interviews with end users highlighted:

- The important role of citizen science particularly in providing large-scale and long-term high quality datasets through mass participation to assess change and for engagement, awareness raising and social benefits.
- A tendency for end users to perceive the quality of citizen science collated information as low thus detracting from the use of such information. However, the semi-systematic review and case studies provide strong evidence that the perception of citizen science as providing low quality information is misguided.
- The potential to make considerably more of citizen science by end users than is currently the case. Specific opportunities were highlighted including:

    - Supporting the information collected by professionals and thus adding richness to data sets.

- Gathering species records for baseline data and thus allowing identification of priority areas for case work.
- Surveillance and monitoring of non-native species.
- Directing resources and professional activity.
- Developing policy and ensuring agencies deliver policy goals.
- Ground-truthing and interpreting data, for example confirming forest cover, tracking storm events and channel movements from satellite data.
- Testing and validating interpretation of new equipment.
- Experimentation, for example manipulative experiments.

5.0 Review of Technology available for citizen science

5.1 Aims

The advance in communications technology (especially the internet) over the past decade has been one of the reasons that citizen science has flourished. The opportunities provided by technology can be both exciting, allow innovation, and also be overwhelming. Here, we review some of the roles that technology can play in citizen science, focussing on the good use of technology and making specific recommendations about the available tools, whilst looking to innovations that could inspire citizen science in the future. We focus on:

1. Front-end methods for data collection
2. Front-end methods for visualisation
3. Back-end technology: databases and data management, data flow and data sharing
4. Crowd-sourcing
5. Creating virtual communities
6. Future risks of using technology in citizen science

5.2 Front end technology for data collection

Websites

Websites have become the mainstay of citizen science projects. Almost all extent citizen science projects have a website to promote and explain projects, and a majority collect data via the website (80% of the 211 active projects in our semi-systematic review). Websites and online databases are now a relatively mature technology, so the technological risks associated with them are relatively small (Sullivan *et al.*, 2009).

Project websites (including the database architecture) do require investment but we believe that with a small investment, excellent content-rich websites can be designed, so communicating the aims and background of the project for those who wish to explore them.
we recognise that some websites and the databases behind them represent huge investments of resources and sophistication (e.g. eBird (Sullivan *et al.*, 2009) and BirdTrack; see also cyber-infrastructure in section 3 below).

It is important to regularly check that data entry forms do work and to check the website for out-of-date information and non-functioning hyperlinks (We reviewed some, apparently functioning project websites with a 'latest news' section that was many months out-of-date). Content management systems (e.g. Drupal) can be used, so separating the website design from the website content and allowing non-technical project members to provide and update content. Linking to a blog (freely available through sites such as Wordpress and Blogger) can also allow easy updates. With the potential for high-tech solutions to data submission and visualisation, there is the temptation to over-design and overly-complicate projects and their websites. We would recommend that for small-scale, highly focussed projects freely-available technology is considered. For example, online survey tools (e.g. SurveyMonkey for data capture and visualisation) and free blogs sites for communication. Such sites have the advantage of being reliable and well supported.

One of the challenges of undertaking citizen science projects is that the amount of web traffic cannot be easily predicted. It is therefore important to ensure that database servers can support spikes in traffic (e.g. if a project is featured on national television). Google Maps Engine and Amazon webs service are two possibilities for hosting databases 'on the cloud'. This means that they are not located on a specific computer server owned by the project. The advantage is that being 'on the cloud' they are scalable with demand. The legal and security issues of data protection and privacy need to be considered carefully if personal data are being stored 'on the cloud'.

Strengths of websites

- A relative mature technology.
- Relatively easy and cheap to implement.
- A range of services available, from customisable surveys to bespoke database design.
- Access to the internet is very widespread.
- Relatively easy to provide feedback to participants by giving data visualisation (see the section below)
- Content is easy to add, for example background context to the project.
- Can provide very sophisticated and customisable data visualisation and exploration tools.

Weaknesses of websites

- Usually causes separation between data collection (in the field) and data entry (at a computer), thus increasing the chance that data will not be submitted.
- There is still a small but significant group of people who do not have easy access to the internet – this may be particularly important if you are aiming to engage people from older age groups, lower socio-economic groups etc with your recording project.
- Project websites can become out-of-date quickly and require regular maintenance to ensure that the website and database both work and appear current. It is often not clear when projects are active and when they are dormant (i.e. still functioning but past their active period). Though people may be keen to participate, submitting to a project they later discover to be dormant could be a strong disincentive for continued involvement in citizen science.

Case study: Conker Tree Science

Conker Tree Science is a citizen science project that involved one of the authors (MJOP). Here we use the development of the project to exemplify the use of website technology applicable to other relatively small scale projects. The project team commissioned a web developer to design the framework of the site and the database (with data capture forms and visualisation via simple coloured pins aggregating results at a suitable scale in Google maps). Pins are coloured according to an attribute of the data for simple interpretation. The website content was then created by the team via a content management system provided by the developer. This allowed the website to be developed and enhanced as the project progressed. One challenge was the ability to communicate current activity within the project. Therefore a project blog was set up, linked from the project website, which allowed a separation of the more formal aspects of the project (background, protocols, live results) and more informal communication (new stories, updates, FAQs etc.) via the blog.

Smartphone apps

The increasingly wide availability of smartphones is enabling a revolution in data collection, especially with the use of GPS for accurate geographical locating. The ease of submitting geolocated photographs has made validation and verification (where species, for example, are identifiable from a photograph) feasible.

Many smartphone apps for environmental citizen science have a similar function in allowing users to provide a location (automatically via GPS), submit a photograph and provide a couple of additional pieces of information. Often the photograph is used for the subsequent verification of the information that has been submitted.

Due to the relatively small screen size of smartphones, there can only be a limited amount of background information provided. Partly due to this, the way that people interact with smartphone apps means that the user experience is expected to be intuitive and quick. This requires that design and usability of the app is good and that the amount of data requested is limited (usually based on pressing icons rather than typing data in, and limited to two or three questions per data entry). This can limit their use, but also forces the project team to think very critically about which data are essential and which desirable data are supplementary and can be omitted.

Strengths of smartphone apps

- This is mobile technology, so data can be entered where it is collected.
- Easy submission of photographs, making data validation potentially easy.
- Ownership of smartphones is increasing, having now reached about 50% of the British population.
- The functioning of the app has to be kept simple and to-the-point, due to the relatively small screen size of smartphones.
- The limited about of data that can be collected requires the project team to think critically about the essential data required.

Weaknesses of smartphone apps

- Relatively high cost in the development of smartphone apps.
- Rapid advances in technology, so can become redundant quickly.

- Requirement for apps to be developed for multiple operating systems (especially IOS/Apple and Android)
- Requires good mobile phone signal for live communication with the internet (e.g. uploading photographs). The quality of signal coverage is patchy and focussed on areas of high population density. However, apps can be designed for data to be stored on the handset for later submission to the project database (e.g. Plant Tracker and Project Budburst).
- Versatile apps for data collection (e.g. Epicollect) do not allow apps to be 'branded' thus limiting their use in mass participation projects, while a proliferation of standalone apps could create clutter and be self-defeating.
- Users expect apps to be intuitive and have high usability, which can add to design costs.
- Apps for iPhones currently need to be vetted before acceptance to the App Store (for iPhone apps) or Google Play (for Android apps).
- People who do not have smartphones are automatically excluded from participation. Where it is appropriate, it is valuable to set up website data entry so that keen people without smartphones can still take part.

Opportunities of smartphone apps

- Potentially rapid advances in the development of inbuilt and plug-in sensors.
- Possible opportunities to provide prompts and requests tailored to people based on data and location, e.g. to look out for a specific species or make a specific observation. Careful testing of such an approach would be required to ensure that users feel empowered and not pestered.
- Allows interaction with the user based on their location, e.g. developing geocaching. One current example is the Floracaching game on the Project Budbust app which allows users to search for and record flowering/leafing state of individual trees. Similar projects could be developed for many applications, for recording water flow at specific points in upland rivers, or finding and downloading environmental data from dataloggers.
- It is not yet straightforward to ensure that a smartphone app and a website store data in the same database. This would be hugely advantageous to create single, multi-access databases.

Examples of smartphone apps

- BirdTrack. The development of the UK BirdTrack partnership's web-based platform for recording bird sightings. Sightings can be recording in the field and uploaded later. It provides advantages to the individual (maintenance of lists of birds seen) while making data available for analysis.
- Leaf Watch and Plant Tracker. These two apps were developed by the same team for the collection of geolocated photos. These apps were developed for Android and IOS simultaneously, by coding in HTML5, making it an efficient way of developing apps for multiple operating systems. Details of the development of this app are provided on the project blog.
- Epicollect. "EpiCollect.net provides a web application for the generation of forms and freely hosted project websites (using Google's AppEngine) for many kinds of mobile data collection projects."

- Creekwatch is a project-based app allowing the submission of geolocated photos. The project website is extremely sparse (just one short website page with little explanation of the usefulness of the data), which, in our opinion, may limit its attractiveness to potential participants.
- Project Budburst app. A simple icon-based app that enhances the ease of submitting data to Project Budburst. The choice of when to 'sync' with the project database is made very clear through the app.

Sensors

The use of sensors for collecting data has been increasing with the advances of in-built sensors in smartphones and the development of plug-in sensors.

Strengths of sensors

- The development of plug-in sensors for smartphones allows specific information to be collected from the sensor and combined with other advantages of the smartphone (e.g. mobile connectivity and GPS).
- Plug-in smartphone sensors can be transferred between handsets, while reliance on built-in sensors is dependent on the handset manufacturers.
- Static sensors can be linked to home computers (e.g. weather stations) for the automatic upload of data. In the future sensors could be used to record a wide variety of data (e.g. air pollution). Often people are interested in information about their locality so may be happy to invest in the sensors themselves.

Weaknesses of sensors

- Sensors built into smartphones are likely to vary in their sensitivity according to the handset model, settings etc.
- Results will be biased by where people are (for static sensors) or where they go (for mobile sensors) , so coverage is likely to be highest in areas of high population density.
- By automating the communication between the sensor and the database, it removes people from the loop, thus potentially removing the valuable aspect of engagement and education in citizen science.

Opportunities of sensors

- Future development of built-in and plug-in sensors could provide high spatio-temporal resolution data, which may be especially relevant for surveillance of weather, air quality and other physical characteristics.
- Downloading data from remote automatic sensors in the field could become a competitive activity, similar to geocaching.

Examples of sensors

- Street bump. Uses the inbuilt vibration sensor to detect potholes in roads, automatically submitting results. Requires very little input from the user except turning the app on and placing the smartphone on a car's dashboard when driving, thus blurring the distinction between 'citizen science' and 'citizen sensing' (described in the section below).
- Wikisensor. Turns an iPhone into a radiation sensor using the in-built camera.
- Radiation watch. A plug-in radiation sensor that uses the capability of the GPS via a smartphone.
- Citizen sensor. A plug-in sensor for pollution detection that uses the capability of the GPS via a smartphone.
- iBats. A smartphone app that works with a bat detector, plugged into the smartphone, for people taking part in standardised surveys.
- Weather Observations Website. People can either manually upload data from their weather station or automatically upload the data.
- Public lab. A project/community "promoting action, intervention, and awareness through a participatory research model". This community is seeking to develop DIY projects (including modifying cameras to create infrared cameras, and kite-based remote sensing) to engage people with science.

Image and sound analysis – extracting information

Citizen science often requires that people interpret things they sense in the natural world and submit a summary (e.g. a measurement from a meter, a species identity, or a count). However, an alternative is for people to act as collectors of samples (e.g. images or sound recordings) from which information can be extracted in an automated and systematic way. Although image and sound analysis is in its infancy, we believe that this could be an important feature of citizen science.

One of the few examples of image recognition analysis applied to environmental data is the server-side technology behind the Leafsnap smartphone app. Here, photographs of leaves are submitted, automatically identified (via a pattern matching algorithm comparing the photo with photos of known leaves), and the identification passed back to the users. Another project under development is the automatic identification of individual penguins from patterns of their spots, via images taken by smartphone cameras (Spot the penguin). The iBats programme uses a bat detector to plug into a smartphone for the automatic geolocation of sound files that are automatically uploaded to the database for later analysis.

This approach could prove to be very useful for the automatic extraction of species identity from sound recordings (of birds, Orthoptera, anurans or bats). Computer-generate identification would provide fuzzy identification (i.e. probabilities of being each species), so analysis would need to take account of this. Analysis of samples, such as images or sound files could be performed locally, e.g. on a smartphone handset, or on the server-side, so requiring the original data to be uploaded. Current processing power and memory of smartphones is likely to limit these opportunities, but this could become feasible in the near future.

Although there may be advantages with developing novel software for undertaking image and sound analysis, there is a wide range of extant software (e.g. music recognition smartphone apps) that serve a similar purpose. It may be cost-beneficial to adapt or utilise such software, especially if it is open source.

Strengths of image and sound analysis

- Automated identification and analysis overcomes some of the variation in data quality that can be a problem with citizen science.
- Automated analysis can provide the participant with information they would not otherwise have (e.g. an identification of a sample) and so provides an incentive to continue being involved.

Weaknesses of image and sound analysis

- If the analysis is carried out on the client-side, then analysis is limited by the processing power and/or storage capacity of the device. This may be a limitation for smartphones.
- If the analysis is carried out on the server-side, then there needs to be good connectivity to allow data to be uploaded to the server. Again this may be a limitation for smartphones, especially since a gap between recording the data and then uploading it to receive feedback will act as a disincentive for people's involvement.

Opportunities of image and sound analysis

- As image and sound recognition becomes increasingly advanced and handware (e.g. smartphones) become increasingly sophisticated, there are increasing opportunities for providing participants with feedback and so enhance their enjoyment and learning opportunities.

5.3 Front-end technology for visualisation and analysis

Visualisation of data in real time is one of the key ways to enthuse and motivate volunteers. It enables them to see their contribution, alongside those of other participants. It is also a way of engaging people with science because they are able to interpret the data. Some forms of visualization can be extremely sophisticated and customizable (e.g. Juturna), although this is rarely necessary. Very sophisticated visualisation can be counter-productive, because it is less stable than simple solutions and can be confusing for users. However, customisable data visualisation tools can provide new insights into complex data (e.g. BirdViz) (Ferreira, Lincs, Fink *et al.*, 2011).

For providing live results, tools such as Google Maps have been very widely used. It is worth considering summarising results at an appropriate scale, to reduce the clutter in the map, and the amount of data to be downloaded. Google Maps provide tools for aggregating records at appropriate scales, allowing zooming in to individual records (location and details of the record), although consideration should be made of data protection and privacy. Practically, it should be noted that producing live maps from the database places demands on the server. This can, in the extreme, lead to the server crashing and can cause delays in graphics or maps become viewable, to the detriment of the website user. These demands can be reduced by: (1) presenting only a summary of the data (at the appropriate scale), (2) presenting a snapshot in time, which is updated intermittently, (3) not putting the map on a webpage that will be frequently accessed.

From our semi-systematic review of citizen science, we observed that maps are the main form of visualising citizen science data. Graphs may sometimes be used to summarise data, but are less commonly used to summarise live data (though see examples such as Evolution Megalab in which graphs are combined with maps and OPAL Air survey in which graphs are used in conjunction with maps). Often the use of graphs, maybe in conjunction with maps, would allow easier interpretation of the data and so should be considered more frequently.

Visualisation could also provide the results of real-time analysis of data. Although we know of no instances of this so far, this is a vision for developing predictive maps of invasive species presence which are updated as new data are submitted (Graham, Newman, Jarnevich *et al.*, 2007).

Finally, one of the roles of visualisation is to demonstrate the activity of the project, which can act as motivation for people to participate. This can be done effectively and simply with automatic counters showing the number of records submitted or people taking part. For projects in their infancy, with relatively few records, this could, however, act as a disincentive for participants.

Strengths of visualisation

- Visualisation of data is the main way in which people will engage with the results of the project, and is especially valuable for mass participation projects.
- Carefully matching the complexity of the visualization to what is required for the project. Visualization is a form of engaging with people, and so should be designed to communicate effectively.

Weaknesses of visualisation

- Very complex maps can be counter-productive because they can result in slow download times and may not be effective in presenting information clearly.
- Very complex visualisation can be confusing.
- If allowing people to zoom in to specific records on the map, then be aware of issues of privacy, for example locating specific addresses. It may be best to limit the ability to zoom or purposely offset points by a small amount just for the visualisation to overcome this potential problem.

Opportunities for visualisation

- Aggregating data (e.g. to a 10km square, or using algorithms in map service providers) can serve well to allow quick downloads of maps.
- It is often best to do something simple but well, rather than attempt highly sophisticated visualisation.
- Consider whether forms of visualisation other than maps, such as graphs, would be useful. In our opinion, maps are a powerful way of visualising data, but graphs are better for communicating the interpretation of the data.

Tools

Google maps - extremely widely used for mapping results from citizen science projects. It has excellent tools and an active community supporting its development.

Google charts - a set of customisable tools that allow the visualisation of data in user-defined ways. These tools are free and well resourced, with a large community of developers.

Fieldscope - a platform under development that provides mapping and analysis tools and is seeking to be strongly linked to citizen science projects.

5.4 Back-end technology: databases and data management, data flow and data sharing

Gathering data for a specific purpose is an important aim for citizen science projects. Often the data collected are highly specific to that project. However, a greater vision for citizen science is the sharing and integration of data (Newman *et al.*, 2012). Currently the landscape of citizen science is fragmented; some projects have highly developed approaches to sharing best practice and infrastructures for efficiently sharing data, while other projects are entirely isolated. One future scenario is that all projects will link to ‘cyber-infrastructures’, i.e. database systems that are inter-operable and ensure consistent data standards.

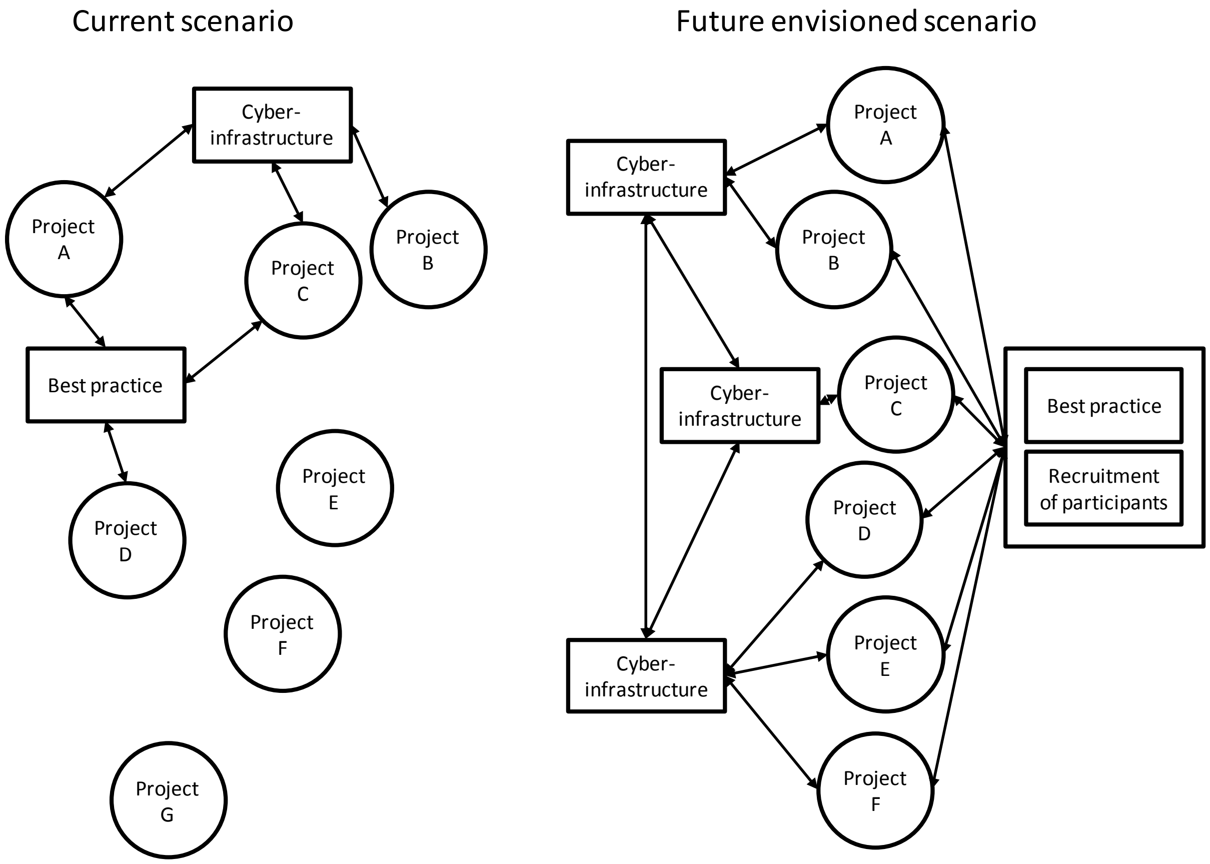


Figure 2. The current and envisioned future scenarios of citizen science (based on (Newman, Graham, Crall *et al.*, 2011, Newman *et al.*, 2012)), showing the importance of cyber-infrastructure linked by web services that permit data sharing .

One efficient way of achieving data sharing is the creation of flexible systems that are inter-operable and ensure consistent data standards. Here the vision is that individual projects running on individual websites will ultimately feed data into databases that interoperate and exchange data (Figure 2; see Indicia case study). In this model there would have to be centralised funding for maintaining and developing these cyber-infrastructures. If the development is open source then it also allows other people to shape the developments and contribute to the project. If the development is not open source then participants are entirely reliant upon the project developers, who may themselves be subject to the vagaries of funding. Indicia is an open source initiative.

Managing data is a key requirement for citizen science projects, especially those that anticipate generating large volumes of data. Many projects are ill-equipped to manage data well (Newman *et al.*, 2011); their focus being on the public-facing aspects of the project. It is our contention that those collecting the data have a moral obligation to ensure that it is managed well (and a legal obligation to ensure personal data is secure). In addition the management of high data standards ensures that it can be re-used to maximise its value.

Initially, one route to encourage data sharing is for individual projects to provide downloadable datasets. Our results show that a minority of projects currently provide this, usually in text form (e.g. CSV files) or point format in KML (so viewable in Google maps). Another approach, which scientists are increasingly encouraged to use, is for the dataset to be stored in a repository, for instance the Environmental Information Data Centre, DataONE or Dryad. Datasets submitted to data repositories require good quality metadata, and if the dataset meets suitable criteria then it can be issued with a Digital Object Identifier (DOI), giving it a unique, permanent identifier.

Sharing data requires good metadata (a good understanding of the limitations of the data) and good data management (consistency between datasets in the format of the elements that are shared, e.g. location and date). The Dyfi Virtual Observatory is a pilot research project that is exploring innovative ways to share and combine data. It will provide lessons learnt as time goes on.

Data sources can also be combined in mashups, in which data sources are combined and aggregated in a way not provided by the original data sources. Often data mashups are map-based, open source projects where users have combined data sources for their own use. We are aware of few examples of environmental data mashups (one example being combining bird sightings from eBird with data on oil spills). Currently, data sources are combined only as part of as academic research projects (e.g. relating species occurrence to environmental data), but the increasing availability of these data sources makes this increasingly tractable.
In making data available for sharing these is a trade-off between providing open access to the original data (which may have inherent biases, gaps in coverage and sampling errors) and providing open access to a summary of the data that have been quality-assured and summarised at a suitable spatio-temporal scale.

Case study: Indicia

Indicia is an excellent example of a 'cyber-infrastructure', which has been designed to support biological recording in the UK, and allows data to be shared easily. Indicia provides a toolkit that simplifies the construction of websites for recording wildlife observations. It provides recording forms that are as simple or advanced as needed, allows photo upload, reporting, mapping and systems for verification of the records. These facilities are provided via a comprehensive set of highly configurable components, allowing diverse and unique recording solutions to be developed whilst avoiding reinventing the wheel and minimising the costs per development. Indicia is an open-source project, developed using standard open-source software components (e.g. PHP, PostgreSQL and PostGIS, JQuery, OpenLayers).

Websites built using Indicia are divided into two key parts - the online recording website itself and a data store known as a Warehouse.

- The online recording website stores all records on the Warehouse. Tools are provided to make the development of this part of the website as easy as pasting a few lines of PHP in to a web page or configuring a content management system (CMS), the open source CMS Drupal being the most popular.

- The Indicia Warehouse can support many surveys on many online recording websites. You can host your own Warehouse or use one provided by another organisation such as the Biological Records Centre.
- The Indicia Warehouse stores data in a standardized format (based on the NBN data model), and enables data to be readily exported to the NBN Gateway, thus maximizing the potential for re-use of data for applied uses.

Practically, Indicia also provides tools embedded to made the expert validation of submitted records very straightforward and allows the automation of communication (acknowledgement emails sent when records are verified, or email alerts when specific species are reported). As well as the development of website interfaces, Indicia allows the integration of data submitted via smartphone apps (e.g. PlantTracker).

An increasing number of organisations and projects are already using Indicia, varying from those interested in recording particular taxonomic groups (British Dragonfly Society, The Mammal Society, Orthoptera Recording Scheme, UK Ladybird Survey), to those interested in specific localities (North East Cetacean project, Norfolk Biodiversity Information Service, NatureSpot), to those with specific purposes (Riverfly Partnership, Black Squirrel Project, PlantTracker, Recording Invasive Species Counts).

iRecord has been created to make it easier for wildlife sightings to be collated, checked by experts and made available to support research and decision-making at local and national levels.

Examples

- Citsci.org. This is a potentially excellent project that seeks to provide hosting and data management for small projects, each of which can use the database within their own website. It seeks to capture data in a form that can be easily shared with other data providers. However, it appears not to be widely used so far.
- DataONE. "...the foundation of new innovative environmental science through a distributed framework and sustainable cyberinfrastructure that meets the needs of science and society for open, persistent, robust, and secure access to well-described and easily discovered Earth observational data."
- EIDC. "The Environmental Information Data Centre (EIDC) is the Natural Environment Research Council's Data Centre for the Terrestrial and Freshwater Sciences."
- NBN. "The National Biodiversity Network (NBN) idea could not be simpler: capture wildlife data once in a standard electronic form; integrate data from different sources; and use the internet to enable data to be used many times in different ways by as many people as possible."
- MEDIN. "The Marine Environmental Data and Information Network (MEDIN) promotes sharing of, and improved access to, marine data."
- DASSH. "DASSH (The Archive for Marine Species and Habitats Data) is the UK Marine Data Archive Centre for benthic survey data of both species and habitats."

- GBIF. “Through a global network of countries and organizations, Global Biodiversity Information Facility promotes and facilitates the mobilization, access, discovery and use of information about the occurrence of organisms over time and across the planet.”
- Dryad. “Dryad is an international repository of data underlying peer-reviewed articles in the basic and applied biosciences.”

Strengths of data flow and data sharing

- Making the data open access and setting up ways of sharing the data will ensure the data increase in value.
- Making data accessible aligns with the aims of 'open science' and related initiatives such as the 'open source' movement.

Weakness of data flow and data sharing

- Creating inter-operable databases will require substantial investment. A careful cost-benefit analysis would need to be undertaken to justify this.
- There is the risk that, if organisations work together, citizen science becomes increasingly professionalised and so loses the vitality and innovation that appeals to participants.
- There is the risk that data could be misused, so emphasising the importance of metadata and adhering to the best possible data standards.

Opportunities for data flow and data sharing

- Communication between organisations (especially government agencies) undertaking citizen science will lead to reduced duplication of effort.
- The possibility that the data will be re-used and shared should be made clear to participants, and issues of privacy and data protection must be considered.
- Working together will lead to greater collaboration (and potentially less competition) between organisations seeking to engage with potential participants. It could result in the production of 'one stop shops' for much citizen science, allowing people to select how to participate more effectively in citizen science.

Risks

Developing inter-operable cyber-infrastructures, i.e. data management systems, into which individual, local project websites feed data, is an emphasis for the future of environmental citizen science. Despite its huge benefits, such as approach does carry some disadvantages:

- Linking to large-scale and centrally-maintained 'cyber infrastructures' could be perceived as representing a loss of independence by individual projects.
- For projects run by professional scientists, e.g. to undertake hypothesis-led science, there are risks of sharing data before publication of results.
- It is essential for the cyber-infrastructures to be as flexible as local needs be, and for resources to be provided centrally for their development and maintenance. Ideally development should be open source, allowing individuals to construct their own solutions.
- There needs to be an appropriate balance between providing off-the-peg solutions for the development of websites for data entry and visualisation (e.g. Citsci, which appears to allow relatively little customisation), and completely versatile solutions allowing local adaption (possibly requiring a software developer locally). Ideally systems designed to manage data from many different sources should provide both extremes

allowing people locally (i.e. maintaining individual websites) to adopt the solution that is best for them (see the Indicia case study).

- Providing infrastructure for projects could have contrasting effects. It could 'professionalise' citizen science, making it harder for small projects to find a place while simultaneously it could permit the flourishing of projects that are successfully able to use the infrastructure provided.

5.5 Crowd-sourcing

Crowd-sourcing is the distribution of tasks to a dispersed group of people. Here, we use the term crowd-sourcing to cover those aspects of citizen science which do not directly involve data collection (which is the main focus of environmental and biodiversity citizen science).

Crowd-sourcing tasks

The human brain is extremely effective at detecting patterns and solving puzzles. An important, high profile aspect, of citizen science has been to 'crowd-source' tasks which are much more easily done by people than done by computers.

Crowd-sourcing pattern detection

- Zooniverse includes many astronomy crowd-sourcing projects and Whale FM which asks people to classify similar types of whale song recording the Atlantic.
- Herbarium@home. Digitizing and documenting herbarium sheets.
- Stardust@home. Discovering particles of interstellar dust from 3D images of gel collectors.
- Salish sea hydrophone network is a relatively low-technology solution to the detection of orca calls from hydrophones. Participants are asked to email detections of orcas or log them via an open access document.
- Instant wild is for the detection and identification of animals from camera traps.

Game playing

- Foldit is a game asking people to solve protein folding puzzles, which has had great success (Cooper, Khatib, Treuille *et al.*, 2010).
- Phylo is a game that asks people to find the best matches between gene sequences. These results are then used as starting places for algorithms aligning gene sequences, which is an effective way of providing solutions to this problem (Kawrykow, Roumanis, Kam *et al.*, 2012).

Citizen sensing

This term is used to describe people as sensors, and their 'reports' can be used as information. In this case people are unwitting participants Examples of this are the harvesting of flicker images and twitter messages to detect outbreaks of sudden oak death (Oakmapper) or the Twitter earthquake detection (Earle, Bowden & Guy, 2012). As social media continues to gain in popularity the ability to detect unusual events is likely to increase, especially with the development of tools, e.g. those used to harvest twitter messages (see the LSE blog post). 'Citizen sensing' may provide useful early warnings for rare, but dramatic events, but information will be 'presence-only' data, so the lack of information cannot be assumed to be absence of the factor of interest. Therefore, citizen sensing, in its own right, is unlikely to be useful for long-term surveillance of the environment.

Crowd-sourcing content provision

The success of Wikipedia, which is an openly-editable encyclopaedia, shows how effective crowd-sourcing can be. This concept has developed to projects such as Openstreetmap, a community mapping project. There is potential for other tasks to be crowd-sourced, e.g. the maintenance of species dictionaries, or the creation of website content, via wikis, which are simply websites allowing users to modify content and usually created collaboratively. This also is a way of creating and engaging with a virtual community around a project.

Crowd-funding

Radiation watch was crowd-funded (i.e. funded by individual backers) in order to develop cheap radiation sensors that could plug into smartphones. For projects that raise particular interest from members of the public, there is the potential to fund them using this model.

Crowd-sourcing and distributed computing

Computer intensive modelling via distributed computing was one of the early examples of 'citizen science' although it is rarely considered now as a form of citizen science because there is no engagement with people. One of the examples of technology used in this way for environmental data is the Climate prediction project.

Strengths of crowd-sourcing

- People can contribute to science in many different ways, not just direct data collection, including analysis, providing content and funding. There is a huge diversity of
- For the crowd-sourcing tasks that are computer-based, participation is open to all and not limited to those in particular places or times of year.
- many crowd-sourced tasks are repeatable and data validation can be easily assessed.

Weaknesses of crowd-sourcing

- One of the important aspects of environmental/biodiversity citizen science is providing people with opportunities to engage with their environment. Many of the types of crowd sourcing discussed above are entirely computer-based and so do not give people direct interaction with their environment, thus limiting a sense of discovery and wonder.

Opportunities for crowd-sourcing

- There is a huge diversity of ways in which people can participate, in its most general sense, in science. Opportunities are only limited by imagination!

5.6 Creating Virtual communities

One of the uses of technology in general is for enhanced communication as shown through the development of social media and social networking (e.g. forums, blogs, Facebook and twitter). Social media can be used within citizen science projects as a way of creating virtual communities, which can enhance the enjoyment and satisfaction felt by volunteers. This is especially important for citizen science projects in which people are geographically dispersed. Communication can be from the project team to volunteers, but also volunteer-to-volunteer, though if coming specifically under the remit of the project then moderators may be needed.

Projects such as iSpot and Project Noah are specifically aiming to create virtual communities of naturalists, and enhance people's experience through time. These are examples of peer-to-peer communication with relatively little involvement from the project team. The data from iSpot is increasingly being harvested by national recorders of different groups of animals and plants. iRecord aims to make it easier for wildlife sightings to be collated, checked by experts and made available to support research and decision-making at local and national levels.

Twitter, facebook and other micro-blogging sites can all provide ways of effectively communicating with people. Blogs (with the ability to comment on blog posts) and forums are more well-established routes to communicate. All these forms of communication are dependent on regular commitment to update and communicate. In our experience there is often a silent, observing majority on online forums, blog comments and other micro-blogging sites so conversations are carried out between relatively few people. Sometimes projects can 'go viral' and news of the project spreads rapidly through social media. This may lead to high recognition, but it is not known whether it leads to increased participation.

5.7 Future risks of using technology in citizen science

Excluding people. The biggest danger of using technology in citizen science is that not everyone is technology savvy. Some people do not have ready access to technology. Others do not want to engage with technology. Using relatively mature technology (e.g. websites versus smartphone apps) will allow projects to be as accessible as possible. Project developers must be aware that by designing technology-based citizen science projects they may be excluding these people. By increasing reliance on high-tech solutions, an increasing proportion of people will be excluded.

Financial cost. Technological innovations have the potential to continue to push the boundaries of what is possible with citizen science. These innovations will often come at a financial cost, so clear decisions need to be made on a project-by-project basis regarding the usefulness of engaging with these innovations. Technological solutions can come with a trade off using extant solutions and making bespoke solutions (e.g. free blogs versus designing project websites).

Variation in mobile connectivity. Future potential in mobile technology will be strongly determined by mobile connectivity, especially as innovations in 4G connectivity (and beyond) extend the gap between the well-connected urban centres and isolated, rural areas.

Volunteer confusion and fatigue. As the ease of establishing new projects has increased with technological innovations and the maturity of website technology, there is the risk that this drives a plethora of projects causing confusion or fatigue among potential contributors. An alternative is to attempt to control the growth of citizen science, so ensuring that data management is good and data collected are fit-for-purpose, yet such centralisation would go against the increasing drive towards the principles of open science and crowd-sourcing.

Increased centralisation. The rapid growth in citizen science over the past decade has been due to both large-scale projects with high financial investment and the 'cottage industry' of smaller projects. This has led to diversity and invention (but also to lack of sharing best practice, isolation and perceived competition). With an increased emphasis on citizen science and data-sharing, there is the risk that the subject could become 'professionalised', to the detriment of the 'cottage industry' creating of inventive projects and the detriment of public involvement in the governance of projects.

6.0 Guide to citizen science: developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK.

It is recognised that effective project design and delivery are essential to the development of successful citizen science initiatives. To support new and existing practitioners of biodiversity and environment based citizen science within the UK, a synthesis of lessons learnt through the case studies, structured interviews and personal experience is presented. This takes the form of a supporting booklet entitled *Guide to citizen Science: developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK (Tweddle et al., 2012)*. The booklet guides the reader through each stage of the project development and delivery process and is structured as in Figure 3. A copy of the guide is available from www.ukeof.org.uk.

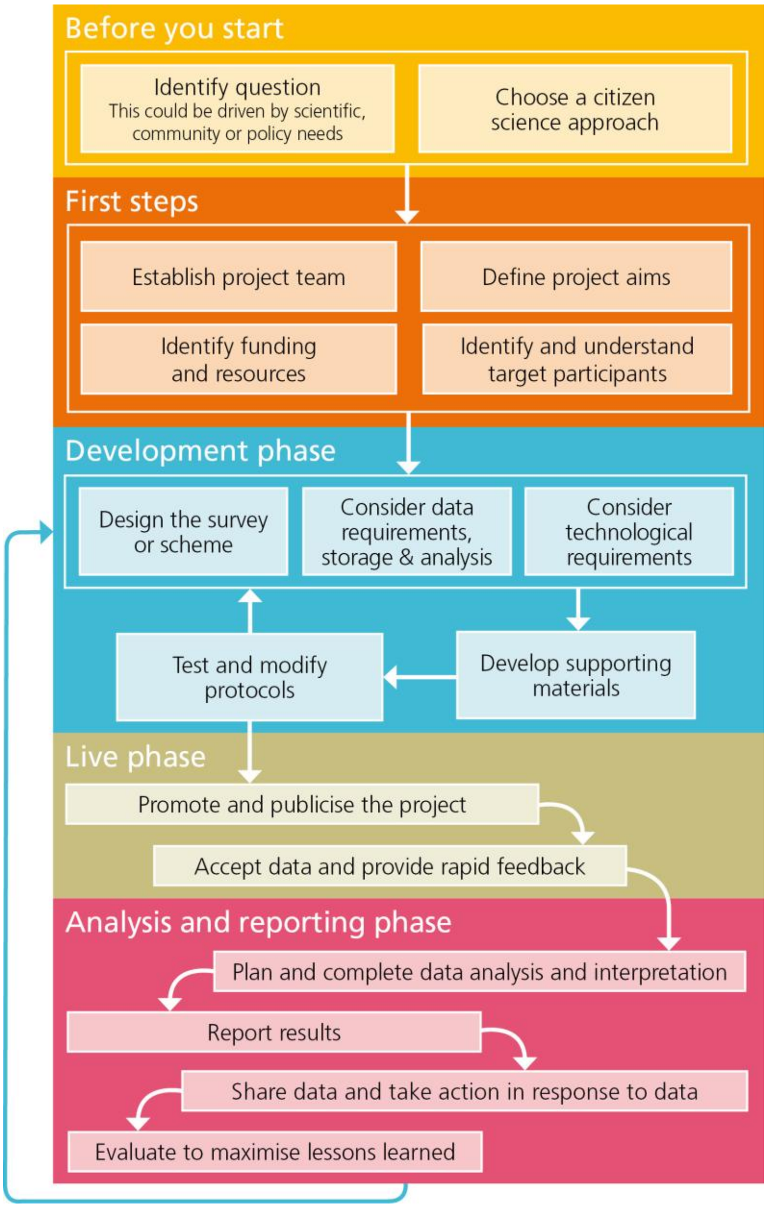


Figure 3. Proposed method for developing, implementing and evaluating a citizen science project within the UK

7.0 Conclusions and recommendations

Citizen science should not be viewed as an easy option by organisations. We recommend that it is viewed as a tool that, when used effectively, can provide great benefit to science and participants alike.

Document quality of data

Our review demonstrates the contribution of citizen science to environmental monitoring, especially to meeting policy-led demands. There is a perception by some potential end-users that citizen science data are poor quality and so have little value. However, in many cases citizen science data are of excellent quality and verification and validation procedures are widely used. We recommend that:

- Appropriate metadata should be provided alongside datasets collated through citizen science to ensure the end-user (both the intended end-user and additional beneficiaries) fully understands the purpose of the data. A number of existing metadata standards are available on-line such as http://www.nbn.org.uk/Share-Data/Providing-Data/NBN-Metadata-Standard.aspx).

- Existing tools and processes for data validation and verification are integrated into citizen science projects. The validation and verification procedures employed should be documented within the metadata.

Work in partnership

Citizen science, providing evidence to inform policy, must avoid duplication of effort and ensure data and best practices are shared widely. We recommend that:

- statutory bodies work together so volunteers have confidence in the value of their contribution.

Citizen science often involves the collation of supplementary data (quantitative and qualitative) alongside the data for which the initiative was originally developed (e.g. citizen science with a biodiversity focus sometimes also collates data on weather and comments from recorders and this could be of value to others). We recommend that:

- Supplementary data should be shared to ensure maximum use. Indeed sharing all data and experiences will lead to greater collaboration (and potentially less competition) between organisations seeking to engage with potential participants. It could result in the production of ‘one stop shops’ for much citizen science, allowing people to select how to participate more effectively in citizen science.

The private sector currently represents an underexplored source of investment in citizen science. Some initiatives (such as commercial ships collecting meteorological data) demonstrate the capacity for increased involvement by the private sector, particularly if useful data can be gathered alongside usual business making effective use of new technologies. We recommend that:

- Consideration is given to increasing the involvement of the private sector in citizen science.

We anticipate that the development of new technologies will continue to provide exciting opportunities for data collection, analysis, data sharing and hence greater use and re-use of citizen science data, in various applications (e.g. regulatory decisions). Innovative projects will continue to arise, offering participants exciting possibilities for engaging with and, indeed, directing citizen science. To ensure maximum benefit from new technologies and reduce duplication of effort, we recommend that:

- Effective communication between organisations (especially government agencies) undertaking citizen science is prioritised.
- An information portal bringing the citizen science community together, highlighting opportunities, sharing experiences and advertising the richness of data available.
- A comprehensive review of current use of data collated through citizen science within the UK is undertaken.

Ensure that adequate resources are available

Citizen science can be cost effective but it is not free. We recommend that:

- Adequate resources are made available and factored into the development of citizen science projects.
- Low cost, open source technology options (such as iRecord and Indicia) are considered before relying on purpose-built options.
- Project developers are aware that by designing technology-based citizen science projects they may be excluding people who do not have ready access or interest in technology. By increasing reliance on high-tech solutions, an increasing proportion of people will be excluded.

Refer to "Guide to citizen science: developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK"

To support new and existing practitioners of biodiversity and environment based citizen science, a synthesis of lessons learnt is presented in the supporting booklet *Guide to Citizen Science - developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK.* This guide (Tweddle *et al.*, 2012)is based on detailed information gathered and analysed as part of this report and should help with citizen science relating to biodiversity or the environment. It is available online: www.ukeof.org.uk and can be freely distributed in its original form for non-commercial purposes.

Appendix 1: Semi-systematic review of citizen science and environmental monitoring projects

Initial selection of projects

We conducted searches with an internet search engine (www.google.com) with the search term *citizen science* (on 11th July 2012). We visited the web pages of the first one hundred hits and followed relevant links on those pages. This search revealed three directories of citizen science projects, Citizen Science Central and citsci (for which we reviewed all projects), and Scistarter (for which we reviewed all projects listed in 'Ecology & Environment'). We considered that this search provided poor coverage of UK citizen science projects (partly because, in our experience the term 'citizen science' is used in the UK for a subset of the types of projects to which it is applied in North America). Therefore, in addition to this search we also undertook an internet search with the term *"take part" environment OR nature* (on 25th July 2012), visited the web pages of the first one hundred hits and followed relevant links. We also included projects listed in the:

- UK-EOF catalogue (http://www.ukeof.org.uk/di_catalogue.aspx)
- SEPA catalogue (http://www.environment.scotland.gov.uk/citizen_science.aspx)
- MBA list (unpublished)

Additionally we included two known to the project team that were not revealed by other searches (specifically Conker Tree Science (which at the time was awaiting inclusion in Citizen Science Central and is now included) and the Arable Bryophyte Survey (a special survey of the British Bryological Society, a society included in the UK EOF catalogue)). All projects were reviewed between 11th June and 8th August 2012. From the semi-systematic searches for citizen science projects we gather 454 candidate projects. Of these candidate projects, we retained 244 projects for full scoring according to the attributes in table 1, but in our analysis we excluded 10 projects that were entirely computer/desk-based because many of the attributes were not applicable to them.

We excluded 70 projects that were primarily education, conservation or volunteering, and 31 projects for which the website sources of information did not work. We wanted to capture the diversity of citizen science projects, so we did not include all of the instances of similar projects (such as water monitoring according to the same protocol but in different catchments, or biological recording of different taxonomic groups). We did ensure that we retained as wide a diversity of projects as possible, given the time constraints on scoring projects. Each project retained for scoring took 5-10 minutes to review and score.

Further analysis on these data is underway for submission to a peer-reviewed journal.

Table 1. Attributes used in the semi-systematic review of the citizen science projects.

Name of attribute	Qualifiers (answer options)	Notes
Project name		
Website		Website name
Brief description	(open text)	
Related projects		Identify projects from the same organisation or initiative
Date of review	(date)	Date that the project was reviewed
ILLUSTRATIVE VARIABLES (we wanted to see if the variation across the projects related to specific prior attributes)		
Category of project	BIOMON, WATMON, CS, BIOREC, ENVREC, ENVMON, HYPLED, PHENOL or TECH	Hypothesis-led (HYPLED) projects were those clearly focussed on testing an hypothesis. Monitoring projects (...MON) required a larger investment by the participant than recording projects (...REC). We differentiated projects that were focussed on biodiversity (BIO...), water (WAT...) and other environmental aspects (ENV...). Phonological monitoring (PHENOL) is a special case of a monitoring project. We used the term 'Crowd-sourced projects' (CS) to refer to those entirely computer-based projects. A few projects were providing or developing technology (TECH) for future, wider use.
Domain of research	TER, FW, MAR, ATM, AST or ALL	The dominant domain of research: terrestrial (TER), fresh water (FW), marine (MAR), atmospheric/climate/weather (ATM), or all (ALL).
Region of research	USA, UK, NAm, EUR, SOU, INTL	USA and UK refer to projects specifically within those countries, while NAm and EUR refer to the continents of North America and Europe more generally. SOU refers to projects in the southern hemisphere (mostly Australia). Projects with an international scope (INTL)
Project still active?	Yes or no	It would have been difficult to determine projects that were dormant (i.e. the website was still functional, but active data gathering had ceased)
Field of research	Biodiversity or environmental	A broad categorisation. A few projects overlapped these categories.
Type of project	Contributory, collaborative or co-created	
Health and safety instructions	Comprehensive, brief, none or don't know	An aspect of project management

Name of attribute	Qualifiers (answer options)	Notes
DESCRIPTIVE VARIABLES		
Lead partner	Academic, NGO, Government agency or commercial	This was sometimes difficult to unequivocally determine.
Number of other partners that are: academic, NGO, government agencies, commercial	(counts)	Counts of each were included in the database, but only the total number of partners was included in the analysis
Aims	Not stated, vague or specific	'Specific' aims made clear why the data were useful, while 'vague' aims expressed a less precise expectation that the data would/may be useful.
Geographic scope	Local, regional, national or international	'Local' projects focussed on a single site, 'regional' projects focussed on a larger region within a country, 'national' projects extended across a country (or two neighbouring countries), while 'international' projects extended over more than a couple of countries. The specific geographic scope was also noted.
Selection of sites	Pre-selected (by project) or self-selected	For 4% of projects this question was not applicable because the project was entirely computer or desk-based. These projects were retained in the database, but excluded from multivariate analysis.
Routes to involvement	Website, smartphone, social media, email, SMS (text message), postal mail, and/or personal invite	Identifying the main ways in which people would participant in the project.
Support provided	None, in advance, personal training, supporting material, and/or online media, or don't know	Identifying the main routes by which participants would receive support
Clarity of aims communicated	None given, vague, clearly stated	
Background context	Minimal, some, content-rich or don't know	Assessment of the amount of relevant background context to the project, whether 'minimal' (a short paragraph or two), 'some' (a page) or content-rich (a website providing much background context).
Targeted at school children	Yes or no	Projects targeted at school children provided resources aimed at children or teachers
Targeted at experienced people	Yes or no	Projects requiring a degree of expert knowledge before taking part (e.g. the ability to identify birds)

Name of attribute	Qualifiers (answer options)	Notes
Is registration required?	Yes or no	An indication of the accessibility of the project
Are one-off snapshots sufficient?	Yes or no	An indication of the complexity of the project. We defined ‘one-off snapshots’ as recordings that can be made in less than 5 minutes
Are repeat visits essential?	Yes or no	An indication of effort required
Different type of questions asked?	1, 2-5 or 6+	An indication of the complexity of the project. COMPLEXITY
Is special equipment required?	Yes or no	An indication of the complexity of the project; ‘special equipment’ is anything not normally carried (which varies from the prosaic, such as a ruler, to highly complex sampling equipment borrowed from a lab). We noted the equipment required, but did not seek to classify its complexity. COMPLEXITY
Type of data received	Location, text score/description, photo, other multimedia, physical sample and/or don’t know	An indication of the complexity of the project; list ‘other’. COMPLEXITY
Best quality of the data	Quantitative, ordinal or binary	An indication of the complexity of the questions asked. ‘binary’ would be a presence recorded or yes/nos, ‘ordinal’ would involve scoring according a number of pre-defined categories, while quantitative would be something measured or counted COMPLEXITY
Is quality assurance explicit?	Yes or no	‘Yes’ referred to any explicit indication that the data were checked or verified before use.
Are data available to view?	Full data, summary only, only in a report or not available	Specifically referring to the ability to view the data, e.g. on a website ACCESSIBILITY
How are data presented?	Dynamic (automatically updated) or static	If the data are presently dynamically then it permits immediate feedback of the participants contribution ACCESSIBILITY
Are data available to download?	Complete & open access, access to summary only, no public access or don’t know	Specifically referring to the ability to download and locally store the data. ACCESSIBILITY

Name of attribute	Qualifiers (answer options)	Notes
Start and finish year/decade	(year)	It was often difficult to determine the start year, or even decade, from a project's website, so we lacked information for 44% of projects. Most projects were still active so had no finish date. We therefore report these variables, but *did not use them in the multivariate analysis*.
Volume and units of data contributed to date		Often difficult to determine, and the variation in units makes direct comparison impossible. We therefore report these variables, but *did not use them in the multivariate analysis*.

Technical details of the analysis

Multivariate datasets (such as the scores of lots of attributes across lots of projects) are regularly encountered in biology. Often the desire of the researcher is to summarise the variation in the multivariate data in a simple way, for example, reducing the large number of variables (i.e. attributes in our data set) to a smaller number of variables that are derived from these variables. Principal component analysis (PCA) is one of the best known examples of a technique to achieve this. In PCA, the continuous variables are reduced to a series of principal components, each of which are a linear combination of the original variables, and each of which explains a decreasing proportion of the total variance in the dataset. A small number (usually one or two) of the best variables can therefore be used to explain a relatively large proportion of variation in the dataset. The initial variables are therefore reduced to one or two derived variables (the principal components), so-called dimension reduction. The data can then be re-plotted against the first one or two principal components, to show how projects differ from each other in multivariate space. Additionally, the contribution of each of the original variables to the new derived variables (i.e. their importance) can be assessed and plotted.

Here, we use multiple factor analysis (MFA; Escofier & Pagès, 1994), which is a very similar approach to PCA. We cannot use simple PCA, because some of our data are categorical. To put it simply, when using MFA with nominal variables, it firstly performs a PCA on each of the nominal variables. It then combines these principal components with the remaining original variables in a PCA of the whole dataset. This is a technique that has only recently begun to be applied to ecological data (Baraloto et al., 2010; Carlson, Flagstad, Gillet, & Mitchell, 2010), but has wide applications in reducing the dimensionality of multivariate data. Having performed the MFA, we then used hierarchical clustering on the first two dimensions in order to identify clusters in the projects.

The multivariate analysis was performed in R 2.13.2, using the FactoMineR package http://CRAN.R-project.org/package=FactoMineR (Husson, Josse, Le *et al.*, 2012). A small number of projects had missing values for some attributes. There were automatically imputed in FactorMineR. We were determined how each of the original descriptive attributes related to each of the first three dimensions of the MFA by assessing associated attributes as those that had a correlation coefficient, *r*, with an absolute value of more than 0.4 (Table 2). We undertook cluster analysis on the data of the first two dimensions of the results of the MFA and selected the number of clusters where the partition had the highest relative loss of internia (Table 3).

Table 2. Correlation of the descriptive attributes with the first two dimension of the multiple factor analysis (MFA). '-' indicates attributes that did not have specific values associated with them.

Attribute	Value	Dimension 1	Dimension 2
Lead partner	Academic	0.28	0.11
	Commercial	0.24	-0.18
	Government agency	-0.15	-0.03
	NGO	-0.23	-0.04
Number of other partners (total)	-	-0.05	0.35
Geographic scope	-	0.57	0.20
Clarity of aims communicated	-	-0.21	0.37
Background context	-	0.14	0.59
Repeat visits are required	-	-0.47	0.24
Self-selection of sites	-	0.64	-0.03
Snapshots (brief visits) are sufficient	-	0.59	-0.37
Support provided	In advance	-0.37	0.08
	Online media	0.08	0.33
	Personal training	-0.61	0.16
	Supporting material	0.44	0.50
Registration is required	-	0.17	0.40
Targeting experience people	-	-0.26	-0.11
Targeting school children	-	0.07	0.41
Number of types of data questions	-	-0.27	0.51
Special equipment required	-	-0.47	0.23
Data availability for downloading	-	0.15	0.10
Data availability for viewing	-	0.47	0.17
Dynamism of the data to view	-	0.56	0.00
Routes to involvement	Website	0.39	0.54
	Smartphone	0.41	-0.23
	Social media	0.05	0.12
	Email	-0.05	-0.19
	Personal contact	-0.41	-0.17
	SMS/text message	0.12	-0.08
	Postal mail	-0.17	-0.01
Best quality of data required	-	-0.24	0.60
Data required	Location	0.14	0.13
	Score	0.01	0.36
	Photo	0.51	-0.09
	Multimedia	-0.05	0.05
	Physical sample	-0.30	-0.15

Table 3. The proportion of observed projects in each cluster compared to their expectation according to illustrative attributes. Values greater than 1 indicate more than expected, values less than one indicate less than expected. Our expectation was based on the total distribution of projects in the clusters with 23%, 21%, 32% and 23% of projects in clusters 1, 2, 3 and 4, respectively. Cluster 1 = simple local projects; cluster 2= thorough local projects; cluster 3= simple mass participation projects; cluster 4 = thorough mass participation projects.

Attribute	Category	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Percentage in each attribute category
Domain	All	0	0	1.0	2.9	1
	Atmospheric	0.4	0.8	1.5	1.1	5
	Freshwater	1.2	1.6	0.7	0.6	16
	Marine/shore	0.9	1.4	0.7	1.2	14
	Terrestrial	1.0	0.8	1.1	1.0	64
Type of project	Co-created	3.5	0.5	0.0	0.4	4
	Collaborative	1.0	2.1	1.0	0.0	4
	Contributory	0.9	1.0	1.0	1.1	92
Field of research	Biodiversity	1.0	0.9	1.1	1.0	79
	Environmental	1.0	1.3	0.8	1.0	21
Region	EUR	0.0	0.0	1.8	1.7	2
	INTL	0.3	0.1	1.4	1.9	14
	NAm	0.3	0.9	2.0	0.3	11
	SOU	0.5	1.2	0.8	1.6	3
	UK	1.1	0.8	0.8	1.4	22
	USA	1.4	1.4	0.7	0.7	48
Category	BIOMON	1.3	1.7	0.7	0.5	31
	BIOREC	1.0	0.5	1.1	1.3	35
	CS	2.2	2.3	0.0	0.0	2
	ENVMON	0.7	0.8	1.3	1.1	5
	ENVREC	0.2	0.0	1.0	2.7	8
	HYPLED	0.3	0.7	2.2	0.3	6
	PHENOL	0.0	0.6	1.9	1.1	3
	TECH	0.7	0.0	1.0	2.2	3
	WATMON	1.8	2.5	0.2	0.0	7
Lead partner	Academic	0.6	0.8	1.2	1.2	42
	Commercial	0.0	0.0	1.0	2.9	1
	Government	1.7	1.2	0.8	0.5	15
	NGO	1.2	1.2	0.8	0.9	41
Health and safety	None	0.9	0.7	1.1	1.3	68
	Brief	0.4	2.2	1.0	0.4	9
	Comprehensive	0.9	1.6	1.2	0.2	10

Appendix 2: Case studies

Thirty-three citizen science initiatives were selected from the semi-systematic review using a stratified approach to ensure that the case studies represented the breadth and diversity of citizen science.   People with a lead role in the selected citizen science initiatives were invited to contribute through completion of a case study template. A total of 30 case studies were returned completed.

Audubon Pennsylvania Bird Habitat Recognition Program

Author: Steven J. Saffier (Director, Audubon At Home)

Primary aim of the project: To engage homeowners and other property owners in the ecological restoration of their property, to increase resources for birds and other wildlife, to reduce stormwater runoff and contamination, and to create a healthy and sustainable landscape

Type of project: Contributory

Brief introduction: BHR was created as a way to track the actions of individuals on a wide range of landscape types. In particular, the application is intended to help inform people on the options they have to create a native plant-based landscape that will reduce their own maintenance time and costs while increasing the carry capacity of their property, regardless of size. It also serves as the basis for a "community" of like-minded people who can learn from each other as well as stay abreast of related activities in their region.

Start date: July 2009

Current status: Active

Geographic scope: Pennsylvania

Routes to involvement: On-line application, eNewsletters, Listserve, Forum, involvement in the Bird Town program (which includes workshops and training)

Type of data collated: Percentage of property that is covered in turf grass, percentage of native woody plants on property, nesting bird observations, usage of pesticides, window kills witnessed (y/n), cat kills witnessed (y/n), specific features of habitat garden (water, grasses, etc.)

Data storage and availability: Stored on in-house Access database

Quality assurance: Information provided to us is of "good faith".

Training involved: None for BHR

Partners involved: Through our Bird Town program, we have enlisted the help of 15 (as of today) municipalities which disseminate information and promote BHR to their residents.

Number of participants: 521 properties enrolled state wide.

Successes: I believe that the program has in fact increased the awareness of the importance of native plants in the landscape and has increased the demand for these plants. The program has successfully created the envisioned community where people interact and share their enthusiasm for birds, habitat creation, and ecology. I think we have increased awareness and participation in the Great Backyard Bird Count, an annual Citizen Science program. We have also created habitats on a number of schoolyards in PA.

Lessons Learnt: Constant communication is key to maintaining interest. Incentives for participants (such as coupons or invitations to special invents) are important.

Policy relevance: On the municipal level, our program tackles weed ordinances and other antiquated ordinances that may hamper individual efforts to improve the ecological value of a property.

Project outputs: eNewsletters, occasional surveys to participants.

Big Garden Birdwatch

Author: Dr Mark Eaton (Principal Conservation Scientist - RSPB)

Primary aim of the project: To engage with a mass audience on the subject of garden birds: to raise interest in birds with an audience not always reached by normal conservation engagement, highlight conservation concerns for such species (e.g. House Sparrow), and encourage positive responses such as wildlife-friendly gardening and further monitoring activities.

Type of project: Contributory.

Brief introduction: A long-running citizen science project, the strengths of Big Garden Birdwatch are more obvious on engagement and communication aspects than they are on science. This activity involves an extremely large number of people, many of whom would not class themselves as birdwatchers but are encouraged to watch the familiar birds in their garden for an hour. This raises awareness and, through this engagement, allows the RSPB to build more support for conservation. The release of the results to the media provides the RSPB with its largest media story each year – thereby reaching more people.

Start date: Has run as 'garden birdwatch' since 1979, although some gaps in the 1980s. Became 'Big Garden Birdwatch', with an increase in scale, in 2000. An additional component 'Big Schools Birdwatch' has run alongside BGBW since the mid-2000s.

Current status: Ongoing, held annually on the last weekend in January.

Geographic scope: UK

Routes to involvement: National media, web, face-to-face promotion and collaborations with partners (e.g. supermarkets). RSPB members are engaged through members' magazine. Data can be submitted by paper form (distributed in newspapers and magazines) or online (currently 75% of all submissions received).

Type of data collated: Seventy two species are included on the online form (15 on the paper version) with maximum number recorded within garden over a one hour observation period, plus garden information (size, location, garden features) and types of bird food provided.

Data storage and availability: Databased at RSPB; two years data have been uploaded to NBN, with the intention to make the whole dataset available at some stage.

Quality assurance: 'Unlikely' records (out of range records, unusually high counts) are filtered out using automated procedures.

Training involved: Simple identification guides as provided on paper forms and online.

Partners involved: None, other than some commercial linkups to promote survey.

Number of participants: In 2012, 592,475 people took part in BGBW, submitting 285,440 responses.
Successes: In 2012, BGBW collected 2.94 million records, or 20.5 million if null counts are considered, with a total bird count of 9.2 million.

The BGBW is, as far as I am aware, the largest biodiversity monitoring project (in terms of annual participation) in the world, and is an extremely useful tool for RSPB engagement. Although the simple nature of the survey (encouraging participation) means that results are susceptible to variation (particular weather impacts on the weekend of the survey, given the lack of replication), and the untrained and often inexperienced nature of the observers means the data includes a degree of noise, the sheer volume of data compensates for this. Trends for resident species match those from other monitoring schemes (e.g. the Breeding Bird Survey) closely. The huge sample size allows for disaggregation to results at a fine spatial scale, and have allowed us to (e.g.) target conservation action for House Sparrow, investigate the relationship between increases in some finch species and changes in bird food provision, and map the expansion of the urban non-native invasive Ring-necked Parakeet. The database now holds over 100 million records, and further analyses are planned.

Policy relevance: For several years BGBW data contributed to the 'Town & Garden' wild bird indicator reported as part of Defra's England Biodiversity Strategy indicators.

Project outputs: Limited - feedback to participants, wider public and media – centred around the top ten species and population changes over time. Scientific outputs are planned.

Common Bird Monitoring in Bulgaria

Author: Dr Mark Eaton (Principal Conservation Scientist - RSPB)

Primary aim of the project: To develop a robust, sustainable and low-cost scheme to monitor common and widespread breeding birds across Bulgaria

Type of project : Contributory

Brief introduction: This is similar to schemes that the RSPB has fostered in Spain, Portugal, Czech Republic, Poland, Greece, Romania, and have been developed across many European countries under the Pan-European Common Bird Monitoring Scheme (see *www.ebcc.info/pecbm.html). The RSPB has provided funding and technical advice to help the Bulgarian BirdLife partner, The Bulgarian Society for the Protection of Birds (BSPB), to develop a scheme along the lines of the BTO/JNCC/RSPB UK Breeding Bird Survey. Volunteer observers are trained in a simple bird recording method and assigned a recording square to enable random sampling to produce annual trends in common breeding birds across Bulgaria*

Start date: 2004

Current status: Active, ongoing. RSPB involvement now decreased, as BSPB have the experience to run the project with little outside help and have secured alternative funding.

Geographic scope: Bulgaria

Routes to involvement : Recruitment through BSPB membership, birdwatching networks using face-to-face contact, print media (newsletters, reports) and online. Also through contact with universities, including the incorporation of modules on monitoring involving BSPB staff in teaching, and by engagement with schools. Unlike some NGOs developing similar monitoring schemes, BSPB have been foresighted in targeting young and inexperienced observers as well as the more obvious pool of existing birdwatchers.

Type of data collated: Counts, of all bird species heard or seen, in 200m sections along a 2km transect and using three distance bands. Associated habitat data using a hierarchical classification. Other than some issues of sampling design the survey is a carbon copy of the UK BBS.

Data storage and availability: Data are stored in a database held by BSPB; raw data has not been made available to other parties, although monitoring outputs are shared with PECBMS to contribute to Pan-European trends and indicators.

Quality assurance: Records are validated by scheme organisers and/or local coordinators, using preset limits, knowledge of species' range and of individual observer experience.

Training involved: A series of one and two-day workshops have been run to train observers, alongside training during annual volunteers meetings and through local BSPB group meetings. University students have been trained by incorporating the project into degree courses.

Partners involved: BSPB work with a number of local partners and are now running the scheme under contract to the Bulgarian Govt.

Number of participants: Between 100-150 per annum.

Successes: Approximately 6000 records per year at the 1-km square level, or 30,000 if the recording subunits are counted separately.

The project developed rapidly, increasing in participation from c.50 observers in 2004 to c.150 three years later. Subsequent growth has been slower, with some drop-off in numbers in some years (see below). The project now produces indices of abundance for 38 species, which have been aggregated into the first wild bird indicator (and indeed the first robust biodiversity indicator of any kind) for Bulgaria in 2011 (showing a 16% decline in farmland birds between 2005 and 2010). The scheme is scientifically robust, produces good quality reports and maintains excellent communication with volunteers and to the wider public through mainstream media. It has improved BSPB's standing with govt., with policy-relevant outputs, and has improved the European coverage of the PECBM Scheme.

Lessons Learnt: BSPB are still learning how to improve recruitment and crucially retention of volunteers - although they have followed much of the best practice with this regard, they are struggling with issues posed by a highly mobile population, with young volunteers likely to move following recruitment, many leaving the country for education or employment elsewhere in the European Union. They have learnt a lot about communication of the scheme and it's results to various audiences such as the general public and important policy-makers.

Policy relevance: The project generates outputs that are very policy relevant - bird trends will be valuable for setting conservation policy, identifying priorities and communicating conservation issues. Outputs will allow government to fulfil reporting requirements e.g. against the Birds Directive (species trends) and Rural Development Regulations (farmland bird indicator. Contribution to the PECBM Scheme mean that outputs will influence policy at the European level.

Project outputs: National trends have been produced for 38 species for the period 2005 to 2010, and a national farmland bird indicator produced . Bi-annual newsletters promote the scheme and feedback to volunteers, and annual reports describe the results - see http://bspb.org/monitoring/download/bg/32/State_Common_birds_2005-2010_final.pdf

Conker Tree Science

Authors: Michael Pocock & Darren Evans

Primary aim of the project: Dual aims of public engagement with science and conducting real science

Type of project: Contributory

Brief introduction: "What is happening to our conker trees? They are under attack from alien moths! Take part in our missions to help us understand how much damage is being done, and whether natural pest controllers can help." This project was set up with the aim of engaging people with science through taking part in scientific research – our aim was for effective engagement and real science.

Start date: 2010

Current status: active

Geographic scope: UK

Routes to involvement: website, app

Type of data collated: presence of leaf miner, number of moths & parasitoids reared, type of ground cover

Data storage and availability: via our own database. Up-to-date summaries of the data are shown on the website.

Quality assurance: we have validated each type of data. Usually we have validated a subset of the data (e.g. counts of reared moths and parasitoids, damage scores of leaves). In most cases data collected by the public was accurate, but for one type of data (counts of parasitoids reared) we modelled the error/mis-classification rates and statistically took this into account in the analyses. We also crowd-sourced the data validation of photos uploaded via the smartphone app.

Training involved: none required (full instructions given)

Partners involved: NERC Centre for Ecology & Hydrology, University of Bristol, University of Hull. Funding from NERC. The app was developed by the University of Bristol (led by Dave Kilbey) with funding from JISC.

Number of participants: c. 5000

Successes: 10,000 records submitted (to date) have allowed us to discover novel aspects of the biology of an invasive insect (the horse-chestnut leaf-miner) that is damaging our horse-chestnut trees. It would not have been possible to undertake this study without the involvement of people from across Britain during the whole of the summer months. In parallel, we have engaged with close to 20,000 people (visiting the website or downloading the smartphone app), with about 5,000 people submitted results. It has been reported by local and national newspapers, radio and television and consequently given us opportunities to communicate about our research. The app was featured on BBC's The One Show and reached top spot in the UK iTunes Education chart. Specifically, our analyses have revealed (1) that after the leaf-mining moth has spread to a location the amount of damage it causes increases during the first 4 years, but plateaus thereafter, and (2) that parasitoid wasps increase with the length of time that the moth has been present in a location – a finding in contrast to studies in continental Europe, where the moth has been present longer.

Lessons Learnt: This project would not have been possible without initial small grants of £1500 from RCUK and the British Ecological Society. The success of these initial projects allowed us to win the larger grants from NERC to set up the project and JISC to develop the app.

We have found there is a trade-off between the organic development of the project (which has allowed us to build on our successes, and learn from mistakes as time has gone on) and the value of a strategic overview, for example we have not (yet) combined the data from the website and the app in a single database.

Media attention has been very valuable in extended in the reach of the project. Gathering the attention of the media was only possible because we had such clear public interest ('an invasive pest is damaging our conker trees'), but it seemed very much down to chance whether it was picked up or not. Although the activities are ideal for school children (based on feedback we have received), we have not found an effective way to recruit school teachers, except by personal contact.

The project was very much contributory at the start, but we have shaped the development of the project with ideas received from participants, and we are seeking to increase people's involvement in the direction of the project.

Despite public engagement sometimes being regarded as a peripheral activity by academics, this has opened numerous opportunities for the project team members in media activity, research opportunities, further collaborations and grant funding applications.

Policy relevance: none due to the data directly, though it has been regularly used as an example of citizen science by RCUK and NERC to highlight the importance of public engagement to policy-makers.

Project outputs: article in British Wildlife (July 2011), 1 paper submitted for academic peer review, 2 more papers in preparation.

Corfe Mullen BioBlitz

Author: John van Breda (CM BioBlitz Organiser and Biodiverse IT)

Primary aim of the project: To provide a snapshot of the wildlife found in Corfe Mullen and to encourage participation and awareness of biological recording activities.

Type of project : co-created

Brief introduction (100 words): Corfe Mullen BioBlitz 2011 was an event organised by the village NatureWatch group and Dorset Wildlife which aimed to identify as many species as possible in a 12 hour period. As well as an opportunity for providing a snapshot of the wildlife in the village, the event aimed to introduce members of the public to biological recording and to learn about the wildlife sites in and around the village. The event was attended by people of all ages including a number of experts.

Start date: 28th May 2011

Current status (e.g. active and ongoing or complete): complete

Geographic scope: Parish boundary of Corfe Mullen

Routes to involvement: walks, site visits, moth trap openings and other activities during the day. Face to face interaction between public and experts invited to attend.

Type of data collated: Georeferenced species records, abundance and photographs.

Data storage and availability: All data and photographs are available on BRC community warehouse and provided to Dorset Environmental Records Centre. The records will be provided to the NBN Gateway when the BRC warehouse is configured to do this.

Quality assurance: Most observations were confirmed by experts in the field. Online recording tool ensures basic format of the records was correct.

Training involved: Assumes no prior knowledge. Public were supported by experts throughout the day and allowed to take part in activities such as moth trapping, sweep netting and bat detecting.

Partners involved: Dorset Wildlife Trust, various experts from schemes and societies.

Number of participants: Approximately 100

Successes: The BioBlitz provided records of 762 species, most of them verifiable. The mixing of public and experts on walks was very successful and provided a very productive learning environment. There was a great deal of enthusiasm for the event and a relatively high amount of media interest. Organised walks and site visits were generally well attended.

Lessons Learnt: Whilst some efforts were made to provide an IT infrastructure that would allow the species count to be tallied through the day, there was a reluctance to spend time inputting the data when this would impinge on time spent in the field. Therefore the amount of information digitised during the day was relatively low (approximately 150 species). This difficulty might be mitigated in future by providing a mobile means of registering a species record.

Policy relevance: None directly.

Project outputs: NBN Newsletter article at http://www.nbn.org.uk/News/Latest-news/BioBlitz-%281%29.aspx Interviews on Radio 4's

Scotland Counts Project - The Conservation Volunteers’

Author: Stevie Jarron (Citizen Science Coordinator – Conservation Volunteers)

Primary aim of the project: Over the next 5 years, Scotland Counts will work in four broad areas to achieve a wide range of strategic environmental and societal benefits. We will:

- Increase public knowledge of Citizen Science and confidence to participate
- Facilitate community participation in Citizen Science
- Support learning through Citizen Science
- Engage new audiences with Citizen Science

Type of project: co-created

Brief introduction: Scotland Counts aims to develop opportunities for people in Scotland to get involved in Citizen Science: projects in which volunteers collect environmental data. Main work areas:

- Coordinating existing effort - establishing an informal network of organisations engaged in citizen science, already working with volunteers collecting environmental data. Will increase organisations opportunities to share good practice, resources and training.
- Engaging new audiences - vital to maintain a recorder bank, increase environmental citizenship and provide new opportunities for learning and engaging with natural world.
- Developing new initiatives - explore and identify new opportunities and techniques for data collection by amateur recorders. Developing new projects and technologies involving volunteers in monitoring invasive species, air quality and river levels.

Start date: August 2011

Current status: Active

Geographic scope: Scotland

Routes to involvement: website, email/telephone contact, support material (training, ID aids), personal contact, meeting with other agencies and NGOs, conferences, school support in class, surveys/research , env/teaching trade fairs, ideas fed through a steering group from SEPA, SNH and Scottish Government.

Type of data collated: wide range of data from biological records on paper sheets to environmental monitoring data uploaded directly to websites

Data storage and availability: Data stored by requester and/or end user of data, not TCV**.** All data (except where deemed sensitive) to be made freely available

Quality assurance: new audiences submit their data to organisations already gathering records and able to verify new records. New recorders outwith these organisations are directed to iSpot or encouraged to seek verification from local specialist resources**.**

Training involved: induction training given to teachers and ongoing support offered. New individuals are directed to local courses available through the Environmental and Community Leaders Training Programme. Ongoing training requests are considered as they appear.

Partners involved: Partners in the project are (funding and support from) Scottish Government, Scottish Natural History, Scottish Environment Protection Agency. Support from Education Scotland, The Met Office, Tweed Foundation, Halcrow PLC, Ranger Services, Autism Scotland, Friends of Corstorphine Hill, The Helix project. Many other organisation contacted (over 100) across Scotland to enlist their support and raise their awareness of the projects aims over the next few years. Feedback from these organisations is very positive.

Number of participants: 600 schools pupils in schools citizen science pilot, another 400 adults through other pilots on healthy environment, INNS mapping pilot, Flood Levels monitoring pilot and public engagement for iSpot testing.

Successes: Successes to date are the enthusiasm shown by the directly supported by pilot projects through the coordinator and other TCV staff. School age participants have gained a real buzz from the pilot, where schools set aside a week for the pilot they've found that the subject grew far beyond the week by sheer learner enthusiasm. Where only a few classes were set to take part (eg P6 and 7s), the whole school ended up being drawn in as the message of the pilot use and enjoyment spread.

Real enthusiasm from new participants to go on to learn more, focus their interests and learn a new speciality.

We've observed the aims of the pilot at the highest levels being given resounding backing at events and papers that focus on its outcomes that have been organised by institutions (Gov agencies and NGOs) that were outwith the original partner group at the start of the project. The project is being seen as a major delivery vehicle for many agencies and orgs across the sector to get more data in and more people involved in environmental monitoring and environmental citizenship in general.

General acceptance from early scepticism of the general principles of expanded citizen science activity from both science based institutions and from new public participants from none science backgrounds.

Lessons Learnt: Schools it was found (especially secondary schools) are notoriously short of time beyond scheduled class work and term timetabling. Even contact with the schools themselves at all levels was difficult at the best of times, with large communication gaps. Lesson learned that lots of time may be needed to bed a project in to a school and constant communication attempts are needed to get replies back from schools.

Care needs to be taken that if a pilot is to become mainstream activity that the level of support given in the pilot is not beyond the organisational abilities in wider roll out. Conversely too little support and early enthusiasm quickly fades.

Common Bird Monitoring in Luxembourg

Author: John van Breda (Biodiverse IT)

Primary aim of the project: To provide long term monitoring data of bird populations in Luxembourg.

Type of project: Contributory

Brief introduction: An ongoing survey involving repeat walks at defined transect sites in Luxembourg to record the birds seen along the walk. The participants include both professionals and volunteers Environmental data are captured for each walk.

Start date: 2010

Current status: Active

Geographic scope: Luxembourg

Routes to involvement: Website and contact through local bird groups.

Type of data collated: Species, count, breeding status, wind speed, temperature, precipitation, time.

Data storage and availability: Data are stored in the *Musée national d'histoire naturelle*'s online recording system.

Quality assurance: None but being added through 2012

Training involved: PDF documents are provided to new recorders describing the methodology.

Partners involved: *Musée national d'histoire naturelle Luxembourg*, *Centre de Recherche Public Gabriel Lippmann, Ministère du Développement durable et des Infrastructures*

Number of participants: 37

Successes: Well organised surveys such as this can generate reasonably large quantities of data even with a relatively low number of participants. By repeating the transect walks it gives recorders an insight into changing environmental conditions and bird populations which is perhaps more stimulating than single, ad-hoc records. There is potential for building up a long-term dataset which contains important information relating to climate and biodiversity changes in Luxembourg.

Lessons Learnt: It is necessary to invest in verification systems to ensure that the quality of data can be maintained. Over 31000 records have been collected of 135 bird species so far so efficient mechanisms for identifying potential issues in the data are essential. These mechanisms are being put in place during 2012.

eBird

Author: Andrea Wiggins (Postdoctoral Fellow, DataONE, University of New Mexico and Postdoctoral Fellow, Cornell Lab of Ornithology, Cornell University)

Primary aim of the project: eBird's goal is to maximize the utility and accessibility of the vast numbers of bird observations made each year by recreational and professional bird watchers.

Type of project : Contributory

Brief introduction: A real-time, online checklist program, eBird has revolutionized the way that the birding community reports and accesses information about birds. Launched in 2002 by the Cornell Lab of Ornithology and National Audubon Society, eBird provides rich data sources for basic information on bird abundance and distribution at a variety of spatial and temporal scales.

eBird's goal is to maximize the utility and accessibility of the vast numbers of bird observations made each year by recreational and professional bird watchers. It is amassing one of the largest and fastest growing biodiversity data resources in existence.

Start date: 2002

Current status: Active

Geographic scope: Global

Routes to involvement: Website, BirdsEye and BirdLog mobile apps (3rd party), extensive in-person outreach through presentations by project leaders (and volunteers) at events and meetings.

Type of data collated: Presence/absence and abundance; related location and effort data; number of observers; optionally: age & sex, breeding codes, oiled birds.

Data storage and availability: eBird data are stored in a secure facility and archived daily, and are accessible to anyone via the eBird website and other applications developed by the global biodiversity information community. For example, eBird data are part of the Avian Knowledge Network (AKN), which integrates observational data on bird populations across the western hemisphere. In turn, the AKN feeds eBird data to international biodiversity data systems, such as the Global Biodiversity Information Facility (GBIF). APIs make data available through mobile apps (BirdsEye) and, for example, Google Gadgets.

Quality assurance: Checklist-based data entry alerts contributors to unusual observations at the time of data entry, and requests confirmation and details. Checklists use adapted taxonomy to accommodate species that are difficult to disambiguate in the field and prevent mislabelling and misidentification. Automated data quality filters developed by regional bird experts review all submissions before they enter the database. Local experts review unusual records that are flagged by the filters and correspond with contributors to validate observations. Nonparametric and semiparametric statistical modeling is used to address geographic bias, observer expertise, and other data quality issues.

Training involved: Assumes basic bird identification skills; website provides documentation on system use. In-person presentations also demonstrate website functionality.

Partners involved: Led by the Cornell Lab of Ornithology in partnership with National Audubon. Numerous additional partners run eBird portals (customized front end, shared database and application infrastructure) and collaborate on research projects.

Number of participants: Approximately 25,000 active data contributors and 150,000 data users.

Successes: Nearing the 100 millionth observation (expected August 2012) with over 3 million records per month during spring migration. Over 45,000 total contributors to date. Observations span 800,000 individual locations and 40,000 shared locations in 229 countries, with records for over 9,000 of the 9,969 living species. Data are reviewed by a network of about 500 volunteers who are regional bird experts, and are used for scientific research across several fields (e.g. biology, statistics, computer science), decision-making support for policy and land management around the world, and personal uses. For example, after a quick adaptation to enable data entry on oiled birds, the data collected in the aftermath of the Deep Horizon oil spill have been used to evaluate initial damage and the effectiveness of restoration efforts. The eBird system is used as infrastructure to support local projects, typically without assistance from project organizers, and continued expansion of portals allows local experts to head up data quality management and outreach. Over 80 publications have been produced using project data or about the project, and the 2011 State of the Birds report for the Secretary of the Department of the Interior relied upon eBird data. Other large volunteer bird monitoring projects are now seeking to integrate their data into eBird.

Lessons Learnt:

- Providing feedback that is of interest to contributors is key to motivating ongoing participation; altruism alone is not sustainable. The more instantaneously feedback can be provided, the more motivating it is.
- Engaging local volunteers in “meta” contribution activities (editing shared locations, reviewing data) enables scalability and promotes recruitment, relevance, and data quality that hinges on local expertise.
- By hiring well-known and respected birders to manage the project, the project benefits from the associated positive reputation of these project leaders, their social networks, and their knowledge of the community’s needs and desires. This supports system design and network-based recruitment.

- Establishing a fiscal sustainability plan is also important to long-term adoption and contribution (people don't want to contribute if they think the project will fold). eBird uses grant money for innovation and a combination of other resource flows for sustainability.
- Because they are based on existing birding community practices, the observation protocols for eBird have been fairly stable and only a few minor changes have been made to protocols to improve data quality. This substantially reduced the amount of time to achieving results and makes longitudinal data comparable throughout the lifetime of the project.
- Successfully developing a contributor base can also lead to rising costs for project maintenance and sustainability as project scale increases.
- Openness to data that do not fit the scientific ideal is one of the secrets to eBird's success. The project's policy is to accept all data that participants wish to contribute (and support these contributions with appropriate tools), and expect researchers to select a subset of the data that suits their scientific interests, rather than expecting all participants to follow a rigorous, detailed scientific protocol that would suppress participation. Allowing participants to choose the level of scientific rigor they apply makes it easy for individuals to gradually change existing birding habits to generate more scientifically valuable data.
- Data visualizations are a key tool to communicate with non-scientist audiences, particularly for highlighting the relationships between habitats and species.

Policy relevance: Data are being used internationally for policy development and revision, e.g. evaluations of species risk status, particularly in combination with other long-term data sets. They are used by conservation organizations to help identify and prioritize efforts to protect critical bird habitats. They are also being used for management and policy by federal agencies responsible for public lands.

Project outputs: Over 80 scholarly publications across fields, extensive media attention, regular website feature articles, 2011 State of the Birds report, nearly 100M observations, data products such as the eBird Reference Data Set which integrates bird data with numerous GIS-based covariates, new data modelling and visualization techniques, real-time species range maps (previously impossible), and a very enthusiastic user community.

Galaxy Zoo

Authors: Chris Lintott (Project PI)

Primary aim of the project: To provide morphological classifications of approximately 1 million galaxies.

Type of project: Contributory

Brief introduction: Astronomers face a flood of data, as modern sky surveys collect terabytes of data and capture millions of images, yet in many fields machine learning techniques have failed to adequately replace human pattern recognition as the best way of assessing this data. Galaxy Zoo has recruited hundreds of thousands of people who have submitted approximately 200 million galaxy classifications through a dedicated web interface, and also provides support for those who are inspired to carry out more detailed research. Human involvement on this scale also allows for serendipitous discovery of unusual objects despite the massive scale of the datasets involved.

Start date: 2007

Current status: Active

Geographic scope: Worldwide

Routes to involvement: Website + iPhone and Android apps, promoted via Twitter, blogs, podcasts as well as traditional media.

Type of data collated: Morphological classifications, user behaviour data and discussion forum contents.

Data storage and availability: Data published in professional journals, available at data.galaxyzoo.org and submitted to repositories.

Quality assurance: Multiple classifications of each image, with users weighted against performance metrics.

Training involved: Very brief tutorial incorporated in the latest version of the site, but design emphasises minimising the training required.

Partners involved: Core team at University of Oxford, Adler Planetarium Chicago, University of Nottingham and University of Portsmouth. A science team of ~30 people leads the project.

Number of participants: More than 300,000 people

Successes: Galaxy Zoo has produced more than 30 peer-reviewed papers, several of which are amongst the most highly cited in the field. The majority of these make use of the final catalogues assembled from multiple classifications per object, highlighted in particular the distinction between colour (which is sensitive to recent star formation) and morphology (sensitive to the integrated history of the galaxy being studied). Studies of barred and red spiral galaxies are of particular importance. Critically, there has also been substantial follow-up of serendipitous discoveries using facilities such as the Hubble Space Telescope. These include the galaxy-sized ionized gas cloud, Hanny's Voorwerp, and its analogues, and the small round green 'peas', the most efficient sites of star formation in the local Universe. In several cases volunteers have been responsible for more than simple classification, carrying out investigations into interesting objects themselves thanks to the provision of links with professional data sets. The data from the project has also been used by a series of machine learning research groups, primarily to investigate the effect of extremely large data sets on classification efficiency. Finally, Galaxy Zoo has inspired the creation of the Zooniverse, a portal and software platform for a very disparate group of citizen science projects in fields as different as ecology and papyrology.

Lessons Learnt: Successive iterations of Galaxy Zoo are available at zoo1.galaxyzoo.org, zoo2.galaxyzoo.org and zoo3.galaxyzoo.org and, when viewed in contrast to the existing site, demonstrate our increasingly clear understanding of volunteer motivation and behaviour. Tutorials, for example, are now incorporated into the classification interface itself, an arrangement which allows for immediate engagement in the primary task of the site. The use of new web technologies, particularly HTML5 and Javascript also now allows for a smoother and more easily scalable experience especially when the site is busy. Another major change is the move away from the simple forum used in advance toward the integration of discussion with the classification process itself thanks to the custom-built (and open source) 'Talk' object-orientated discussion system. The issue of feedback to volunteers continues to be a difficult one; naively giving feedback resulted in an overall decrease in classification quality as the motivations of volunteers (we surmise) switched from 'wanting to contribute' to 'wanting to complete the game'. Initial efforts to incorporate Galaxy Zoo into classrooms are beginning to be successful, with the development of specific interfaces for classroom use an important next step.

Policy links: Galaxy Zoo has become a model for a new kind of data analysis citizen science project, proving highly successful at recruiting and motivating an engaged population of volunteers.

Cost: Initial development contributed by volunteers.

Garden BioBlitz

Authors: Richard Comont (Garden BioBlitz – volunteer scheme organiser)

Primary aim of the project: To collect & validate data on the distribution of wildlife in gardens across the UK

Type of project: Co-created

Brief introduction: Gardens can be some of the most biodiverse and yet least accessible habitats in the UK, due to their private ownership and personal nature. The rise of the internet and increased availability and affordability of digital cameras has led to a surge of interest in natural history in the UK, and made taxonomic expertise more accessible than ever before. Combining these two factors with a desire to introduce people to the small-scale but spectacular wildlife living around them, the Garden BioBlitz was launched (via a trial event in 2012) to survey the wildlife of gardens.

Start date: 2012

Current status: Active

Geographic scope: UK

Routes to involvement: Website (with online recording), Twitter.

Type of data collated: Species, presence/absence (often abundance), major habitat features of the survey area.

Data storage and availability: Data available through the iRecord website (www.brc.ac.uk/iRecord), and will feed into the NBN Gateway (www.searchnbn.net).

Quality assurance: Species validated by experts where possible.

Training involved: Website contains instructions on how to carry out a BioBlitz, and provides links to identification resources. Feedback provided on photos via Twitter (@gardenbioblitz)/iSpot(www.ispot.org.uk).

Partners involved: Currently none, but using iRecord (Biological Records Centre (BRC) within the NERC Centre for Ecology and Hydrology) and iSpot (Open Air Laboratories (OPAL) partnership).

Number of participants: 50 (trial event).

Successes: 1698 records of 782 species received from England, Scotland and Wales, with a week remaining before the deadline for this year's event, which compares well with 'normal' BioBlitzes. The trial event generated widespread interest in the wildlife to be found in gardens, and the resources available online for identification.

Lessons Learnt: Real-time identification and high-speed feedback to recorders (particularly via Twitter but also iSpot and Flickr) fosters a 'community spirit' amongst recorders and encourages participation. Use of a small number of 'target species' would be good to incorporate, both for providing records (especially if under-recorded species are picked) and encouraging participation by providing a focus for new recorders.

Policy links: None

The Great Eggcase Hunt

Author: John Richardson (Conservation Officer – Shark Trust)

Primary aim of the project: To identify critically important nursery areas for skates and rays (and a small number of oviparous sharks); identification of these areas will enable the Shark Trust to propose conservation measures, which may help to reverse population declines observed for some species within this group.

Type of project: Contributory

Brief introduction: In recent decades populations of several species of skate and ray around the British coast have experienced population declines. The empty eggcases that wash up on beaches all year round are an easily accessible source of information on the whereabouts of skate and ray nursery grounds. The identification of these areas, critical in elasmobranch life-histories, will enable the Shark Trust to propose conservation measures, which could play a vital part in reversing the decline of this group of animals.

Start date: 2003

Current status: Active

Geographic scope: Primarily UK – with significant input from Ireland and some of coastal European nations

Routes to involvement: Eggcase ID leaflets and hardcopy recording forms; www.eggcase.org website – wide range of resources and online ID key; Eggcase Hunt events regularly throughout the year (mostly during summer)

Type of data collated: Data collated includes number of eggcases found, with all cases identified to species (eggcases of approx. 11 elasmobranchs are found in UK and Ireland). All finds are georeferenced, with date and descriptive location, as well as recorders details. Digital photos of eggcases are encouraged and stored. Actual eggcases are also sent to the Trust, these are identified and recorded.

Data storage and availability: Data is currently stored on Shark Trust database. The Trust is waiting for the completion of a Marine Biological Association (MBA)-maintained database, in which all eggcase data will be stored, and be publically accessible.

Quality assurance: None. Although current Shark Trust spreadsheets were put together by the MBA's DASSH office.

Training involved: Some training is required for accurate data entry and use of Microsoft Excel spreadsheets (currently holding all project data); skate and ray identification skills, as well as the ability to accurately ID eggcases to species is also necessary.

Partners involved: There are no partners involved in the project, although it has benefited financially from a number of funding organisations – most notably the Save Our Seas Foundation (SOSF) at present.

Number of participants: Approximately 800 recorders have contributed records since the beginning of the project. Some of these are organisations, who collate and report findings by large groups of people – so the 800 figure is probably much higher.

Successes: Approximately 31,500 eggcases have been recorded since 2003, by more than 800 people and organisations that, together, represent a considerably larger number of people. Records have been received from all parts of the UK and Ireland, from Shetland to the Scilly's to the Channel Islands. The project also receives records from coastal Europe, Africa, North America and Australia. The project is playing an important role in helping identify important egglaying and nursery areas which may, in time, benefit from protection from extractive industries, in the process reversing population declines observed for a number of elasmobranch species. However, perhaps the most tangible success of the project to-date is raising the profile of skates, rays and dogfish. These species which often fall in the shadow of more charismatic elasmobranchs such as Porbeagles, Basking Sharks and Blue Sharks; the GEH is an excellent platform for demonstrating to the wider public the importance of these lesser-known species to healthy marine ecosystems.

Lessons Learnt: The Trust has focussed on developing and providing excellent quality, easy to understand resources for the GEH, for use by other organisations and individuals. This relatively low-cost, low-key project (from the Shark Trust point of view) is providing an excellent platform for raising awareness of threatened species, as well as producing valid scientific data. The family-friendly, easy to run/participate-in nature of the GEH has seen it develop in a flagship project for the Shark Trust.

Policy relevance: Verified eggcase records (i.e. species to which each eggcase belongs are verified by Shark Trust staff) provide useful data, particularly when viewed in conjunction with data from the likes of the Cefas-run ground fish trawl programme. The GEH provides a useful, informative additional 'layer' to spatial planning and maps – hence its potential use in identifying geographic areas of critical importance to a number of elasmobranchs – several of which are listed in threat categories by the IUCN.

Project outputs: Peer reviewed paper (in conjunction with Cefas) is in the pipeline; reports and newsletters re. the GEH are produced each year for a number of stakeholders – including project contributors, funders, media – online, magazines, Finding Sanctuary - marine protected area (MPA) developers in the South of England.

iSpot

Authors: Martin Harvey and Jonathan Silvertown (OU)

Primary aim of the project:

To encourage and support people in learning about wildlife, especially how to identify it

Type of project: Co-created – iSpot content is almost entirely contributed by the iSpot user community, which is diverse and includes people new to wildlife-watching alongside national and international taxonomic experts

Brief introduction: iSpot is a website that helps people learn about wildlife, using social networking technology to link novices and experts. The main activity on iSpot is the sharing of wildlife observations, with identifications and/or confirmations provided by the iSpot community. Alongside this activity, iSpot has a number of other projects, including the provision of online identification keys (using an innovative multi-access, Bayesian statistical approach), and an emphasis on outreach to new audiences via a network of Biodiversity Mentors.

Start date: June 2009

Current status: Active and ongoing, developing new links and projects

Geographic scope: Initial funding was for England only (through OPAL, funded by Big Lottery Fund), expanded by The Open University to include Scotland, Wales and Ireland; more recently launched in Southern Africa as a partnership project, an approach that we taking to expand to other countries in the coming year

Routes to involvement: iSpot is based around a publicly accessible website. Alongside this, we have a team of (part-time) Biodiversity Mentors based around the UK and Ireland, who are pro-active in seeking out new audiences for wildlife learning, and promoting the project to the public (e.g. via particular communities and at selected events). In addition, we have organised occasional workshops for particular purposes, e.g. to develop functionality for recording schemes, or to test our online identification keys. We also run an active Twitter account, and publicise the project through various media, including OU links with BBC natural history programmes. At June 2012 we are testing an Android app that will allow uploading of wildlife observations to iSpot via mobile devices, opening up the way for identification assistance to be available at the point of seeing wildlife. An iOS equivalent will follow, and these apps are due to be formally launched later this year.

Type of data collated (presence/absence, abundance, soil temperature etc): iSpot is primarily intended to help people develop knowledge of wildlife and skills in identifying what they have seen, rather than as an online data collection system. However, the observations posted on iSpot (nearly 120,000 of them at the end of June 2012) do constitute biological records, i.e. records of presence of a species at a location on a date. We are working with partners to ensure that these data are made available to relevant recording schemes and, via them, the National Biodiversity Network.

Data storage and availability: iSpot data is able to be viewed publicly on the website, but the full details are stored in a bespoke database, maintained securely by The Open University. Exports from this database are provided to relevant recording schemes. We are in discussion with BRC to see if links with Indicia/iRecord can provide a more efficient way of sharing data in future.

Quality assurance: A major feature of iSpot is its emphasis on validation of species identification. Suggested identifications can be agreed with by others on the site, or if they don't agree they add a further suggestion. A unique reputation management system gives participants a 'score' based on how often their identifications have been agreed with, and this score in turn is used to weight the agreements that they give to others. From this matrix of scores a "Likely ID" is shown for each observation, i.e. the suggested identification that has accumulated the highest score from the people agreeing with it will become the Likely ID. People who come to iSpot as experts (e.g. recording scheme organisers, museum taxonomists) are 'badged' as such and are set up with a high reputation score, so that their opinion carries a suitable high weight in debates over identification.

All users on the site are encouraged to explain ***why*** they are suggesting each identification, rather than just adding the name as a *fait accompli*, so that novices can learn which features are needed to provide a safe identification. Expert users in particular are encouraged to make it clear when photographic evidence is insufficient to make a firm identification, and identifications can be made at genus, family or higher levels in such cases. When this happens users are often guided as to what they would need to do to collect further evidence, e.g. by retaining a voucher specimen and getting in touch with the relevant recording scheme or similar. Although less emphasis is placed on the other aspects of record verification, such as date and location information, iSpot's data entry systems ("Add an observation") do encourage accurate usage, e.g. by automatically showing dates and locations stored with the original digital photos (exif data, where available), and providing searchable/clickable Google maps to specify locations.

Training involved: On the iSpot website there are extensive Help/FAQ sections, and some video tutorials (http://www.ispot.org.uk/help). Support for individual site users is provided via an email contact address. Through our team of Biodiversity Mentors we have organised a range of training events for different audiences.

Partners involved: iSpot has been established by The Open University as part of Open Air Laboratories, a large multi-partner project led by Imperial College (http://www.opalexplorenature.org/). iSpot itself relies heavily on, and is grateful to, over 80 partner organisations (recording schemes, museums, natural history societies, etc.) who provide expertise and involvement on the site; these are listed at http://www.ispot.org.uk/representatives. Further partners are involved in developing the site internationally, e.g. SANBI (http://www.sanbi.org/) in South Africa.

Number of participants: Currently (25 June 2012) iSpot has 18,830 registered users. Over 40% of these have added at least one observation to iSpot, and others have contributed comments, identifications and/or agreements. In addition, iSpot is frequently accessed by non-registered users who are able to browse all the material on the site without having to register; over 300,000 unique users have visited iSpot to date, with an average visit duration per session of over 9 minutes.

Successes:

- Nearly 19,000 people have now registered on iSpot, from a variety of backgrounds and including many who are new to observing and identifying wildlife.
- iSpot users are able to learn from their interactions with a friendly community that includes over 100 recognised experts as well as representatives from more than 80 recording schemes, natural history societies and museums.
- Data associated with verified observations on iSpot is being passed to recording schemes, providing new information for them and enabling anyone to contribute valid biological records.
- iSpot as a website is being successful in encouraging people to go outdoors and get involved with wildlife observation, both directly and via the outreach work undertaken by our Biodiversity Mentors.
- At least one species observed and identified via iSpot proved to be new to Britain: the Euonymus Leaf-notcher Moth *Pryeria sinica* (http://www.ispot.org.uk/node/7407); a second observation, of the bee-fly *Systoechus ctenopterus*, may also be new to Britain but has not been possible to confirm beyond doubt (http://www.ispot.org.uk/node/101288); many other rare and unusual species have been reported via iSpot.

Lessons Learnt:

- Although iSpot has undoubtedly been successful in introducing online activity and social networking to people who had not previously had the opportunity to experience such things, it remains the case that regular access to the internet is not available to all, and for some communities this is a barrier to participation.

- iSpot has been successful in engaging people with a wide range of taxa, including many that may be considered 'specialist' or even 'obscure'; however, it is clear that some taxon groups are more amenable to identification from photos than others, and thus provide a more rewarding subject for experts to engage with; for instance, fungi and spiders have proved relatively hard to make progress with.

Policy relevance: iSpot's aims in helping people to learn about wildlife and its identification contribute towards the recognised need for increasing the number of people with taxonomic skills; this has been highlighted in a number of government reports, including a report on systematics and taxonomy from the House of Lords Science and Technology Committee (2008). More recently, iSpot was given as an example of reconnecting people with nature in the 2011 white paper *The natural choice: securing the value of nature*. The observation data that is collected by iSpot is passed, via recording schemes, to the National Biodiversity Network, where it becomes available to influence conservation decision-making alongside other wildlife datasets.

Project outputs: Reports for the iSpot project have been drafted as part of the overall OPAL final report, and are due to be published later in 2012. iSpot produces a newsletter twice a year that goes to our team of expert identifiers and scheme/society representatives.

Other research into the learning process as demonstrated within iSpot is currently under way.

Publications referring to iSpot include:

Clow, D., and Makriyanis, E. 2011. iSpot analysed: Participatory learning and reputation. In: *Proceedings of the 1st International Conference on Learning Analytics and Knowledge*: pages 34-43, March 2011. doi:10.1145/2090116.2090121

Silvertown, J. 2009. A new dawn for citizen science. *Trends in Ecology and Evolution* 24(9): 467-471. doi:10.1016/j.tree.2009.03.017

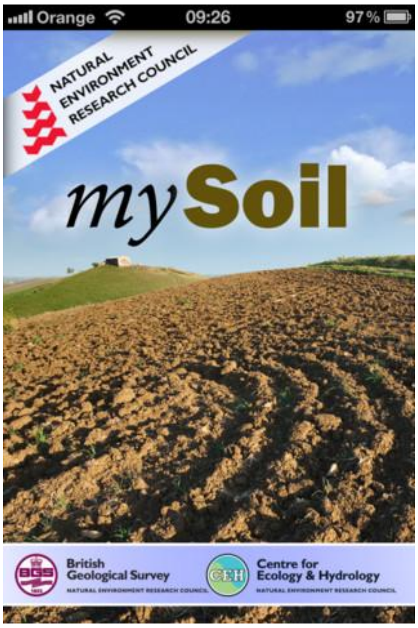
*my*Soil app

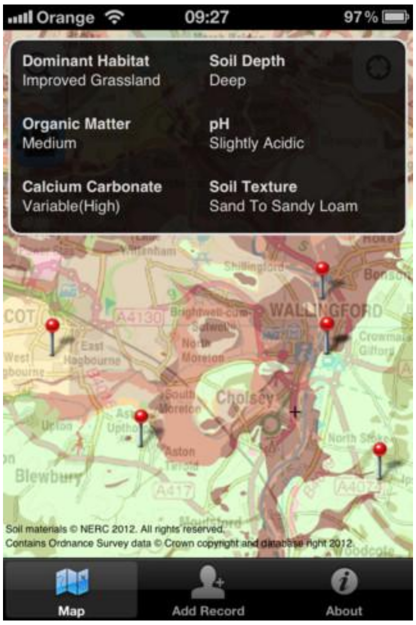
Authors: Wayne Shelley (Applications design); Russell Lawley (Geology advisor); Aiden Keith (Soils advisor); David A. Robinson (Soils advisor); Dan Morton (Land Cover advisor); Jim Bacon (Applications advisor); Bridget Emmett (Soils advisor); Stephen Keightley (Data Licencing); Heather Lowther (Marketing); Gwyn Rees (Advisor); Patrick Bell (System Manager); Carl Watson (programming and database design); John Talbot (programming); Rob Pedley (Database design); Keith Westhead (Project Manager).

Primary aim of the project: To provide open access to NERC soils data for Great Britain

Type of project: Contributory

Brief introduction (100 words): mySoil is a new free smartphone app from the BGS and the Centre for Ecology & Hydrology. mySoil lets you take a soil properties map of Britain with you wherever you go, helping you learn about the soil beneath your feet; taking advantage of your phone's GPS to locate exactly where you are on the latest environmental mapping from NERC. It also allows you to share your soil knowledge and information with other users of the mySoil app using its 'citizen science' interface and maps. It is designed to be a valuable educational resource for anyone to use.





Start date: 2012

Current status: Active

Geographic scope: Great Britain

Routes to involvement: download at iTunes:

http://itunes.apple.com/gb/app/mysoil/id529131863?mt=8

Type of data collated: mySoil contains information from the BGS soil parent material model, the CEH Countryside Survey and the Land Cover Map 2007. Users are presented with a map interface and information screen that provides estimates of landcover type, soil texture, soil pH, soil depth and soil parent material type. Further screens and menus allow the user to upload their own information about soils, including location, photographs, text descriptions, soil texture (one of 6 types) and soil pH class (one of 6 levels).

Map Information within the app is based upon Countryside Survey © Database Right/Copyright NERC (CEH). Land Cover Map 2007 © NERC (CEH) 2011, soils data for England & Wales © National Soil Resources Institute (Cranfield University) (NSRI) and for the Controller of HMSO, 2011, soils data for Scotland SSKIB derived pH for "semi-natural" soils for upper horizon for dominant soil © The James Hutton Institute 2010.

Data storage and availability: Data originates from the Environmental Information Data Centre (http://www.ceh.ac.uk/data/index.html) and the National Geoscience data centre (http://www.bgs.ac.uk/services/NGDC/home.html). Access to the datasets is made via Web Mapping Services (WMS). These services are also largely replicated in the NERC SOIL Portal (www.bgs.ac.uk/nercsoilportal).

Quality assurance (e.g. none, data validated by expert etc):

Application software quality assurance has been carried out by the BGS and CEH development team. iOS and iSTORE compliance has been ratified by Apple Inc.

Contributing datasets have been quality assured via expert judgement (and statistical assessment where relevant) they are maintained, verified and published by the contributing data centres as part of their ongoing research programmes.

Citizen science contributions are moderated for legality and decency of content only, no scientific checks are performed on uploaded data (yet).

Training involved: The app is self contained with use instructions.

Partners involved: British Geological Survey and the Centre for Ecology and Hydrology (Both NERC centre surveys).

Number of participants: To date (27/9/12) the software has been downloaded from the iStore 5730 times. And 368 contributions have been made to the citizen science database.

Successes: App download figures indicate 5730 users. Demonstration and showcasing of the app by NERC knowledge exchange teams at the 4-day Gardeners World event in the UK garnered 700,000 web hits (for mySoil and iGeology) and 6000 user sessions (of an average 4 minute duration .

The app was featured on BBC Radio 2 and 4, as well as in broadsheet press articles (The Times), local press and magazines (Farmers Weekly).

This was a successful deployment of a multi-dataset app on time and to a very small budget. A large number of possible additional features became apparent during development and initial deployment.. Some of these ideas will now be taken forward as upgrades and additional opportunities for user interaction and feedback. The app has acted as a catalyst for BGS and CEH scientists to collaborate more freely and to deliver a whole package of information to users in a compact and meaningful way. Its success has enabled further collaboration between the two research centres.

The app has generated significant interest and feedback from its intended and diverse target audience of gardeners, farmers, students, scientists, land managers, developers and agricultural suppliers.

We have received some international feedback via the citizen science tools, and we are currently aiming to extend the app content to include Europe-wide information by collaborating with the European Soil Bureau.

Lessons Learnt: It was very easy to get carried away with the possibilities for this app. Regularly returning to the original remit of delivering a ‘simple data tool for soil’ enabled the team to rein-in some ideas and deliver simplicity.

There has been significant feedback to suggest users want **much more** information about soils and environment, and that commercial companies have an interest in using the data as well. We perhaps need to spend some more time looking at what extra information we now should add to the app for its next release and also to make alternative access routes to the data (ie via web pages), clearer or easier.

The variability in some of the citizen science outputs could be improved by better use of ‘examples’ either in-app or via support web pages. This will be improved in any future releases, but for future apps we will put more effort in providing initial real-world examples as ‘templates’ for users to consider (taking care not to ‘influence’ the style/content of potential returned contributions.

Policy links: The app is a tool that can easily be downloaded by policy makers to assess the likely soil conditions in areas of interest.

Cost: This is sourced from NERC National Capability.

National Bat Monitoring Programme

Author: Dr Kate Barlow (Head of Monitoring – Bat Conservation Trust)

Primary aim of the project: To monitor population trends of bats in the UK

Type of project: Contributory

Brief introduction: The NBMP runs annual and periodic monitoring of bats to determine their status and deliver information needs for country biodiversity strategies, Habitats Directive obligations, the UK Biodiversity Action Plan and the UK and England Biodiversity Indicators. Information from the NBMP is used to help direct relevant conservation action to sustain bat populations and the habitats on which they depend.

Start date: 1996

Current status: Ongoing

Geographic scope: UK

Routes to involvement: Volunteers sign up to the programme from a wide range of sources. The main recruitment routes are NBMP bat detector workshops, bat group members, the BCT website, other internet sources and through existing volunteers and our country-level Bat Officers. We also take leaflets asking volunteers to 'Help us count bats' to a wide range of events and volunteers sign up as a result of these as well.

Type of data collated: Presence and absence of bat species, abundance data (counts and/or bat activity) and additional information on weather and site details. The programme is comprised of a number of different survey types including Roost Count and Hibernation Surveys (counts of individuals) and Field and Waterway Surveys which provide information on bat activity along transects. Surveys provide information on distribution and populations trends for 11 of the UK's 17 breeding bat species.

Data storage and availability: Data are stored on a bespoke Access97 database at BCT (which is currently being updated to an online website allowing online data entry by volunteers). Data are made available from all surveys via the NBN Gateway with datasets being updated annually. Data are also shared with agencies, researchers and bat groups through data agreements as there is a principle of open access to data within the partnership.

Quality assurance: Different types of quality assurance apply to the different surveys. For example, Hibernation Surveys are carried out by experienced and licensed batworkers, species identification at roosts for Roost Counts is verified by local bat groups or through recording of bat calls and training is provided on use of bat detectors (see below). Outliers and unusual observations in the datasets are checked annually during analysis.

Training involved: The NBMP has a training programme and strategy which involves delivery of bat detector training workshops annually across the UK (through NBMP staff and a network of trained volunteer Regional Bat Detector Workshop Leaders), plus additional training material available online such as a sound library, videos and online tutorials. All volunteers are encouraged to take part in training, although it is not compulsory. Some of these workshops are targeted in areas where number of NBMP volunteers is low. The overall ethos of the training is to provide opportunities for volunteers to enhance their skills and to extend participation in the programme as a whole.

Partners involved: The programme is delivered through a Memorandum of Agreement with partners BCT, JNCC, CCW and Defra. NE also contribute to the NBMP separately to the MoA.

Number of participants: Currently 2299 volunteers are signed up to the NBMP. Since 1997 over 3000 volunteers have taken part in surveys at more than 5800 sites. Since 2008 more than 1000 volunteers have taken part in surveys every year.

Successes: The NBMP is the longest-running, purpose-built, multi-species monitoring programme for mammals in the UK. It provides statistically defensible population trends for 11 of the UK's 17 breeding bat species at a UK level. It has mobilised volunteers across the UK to take part in bat surveys over many years. Some volunteers have taken part in surveys every year since the programme was started in 1997. The programme has provided training for thousands of volunteers: currently around 30 workshops are delivered each year with around 20 participants on each workshop. It has contributed to and influenced key government biodiversity monitoring and reporting obligations including biodiversity strategies, Habitats Directive and the EUROBATS agreement. In recent years the NBMP work programme has expanded to include a number of collaborative research projects and partnerships which utilise NBMP data or adopt its techniques, for example agri-environment scheme monitoring in Wales, assessing the impacts of climate change on UK Biodiversity, studying the ecology of urban bat populations and improving our understanding of how bats use the landscape.

Lessons Learnt: The NBMP was designed to encourage maximum involvement of volunteers and to be as inclusive as possible, whilst also using the best available survey techniques and technologies available at the time. In a recent survey of our volunteers we found that the majority take part because of an interest in bats and wildlife, but a desire to make a difference and contribute to bat population monitoring and conservation is also important to many of our volunteers. Retaining volunteers within a long-term monitoring programme can be a challenge as we are asking people to repeat the same survey year after year. It is important to continue to provide feedback to volunteers to retain their interest and ensure that the importance of their contribution to the programme is acknowledged. The programme is an integrated one and the importance of using more than one survey method to monitor bat species has been highlighted by some differences in trends from different survey types – there is still more work to fully understand the trends. Additional research is also needed to provide a full understanding of bat populations and drivers of change, which cannot be done within the programme itself. Technology has also moved on since the start of the programme with many new developments in bat detectors over the last 15 years. Integrating new technologies to maintain the use of the best available technology within the programme is a current challenge, whilst retaining the inclusiveness of the programme.

Policy relevance: Of key importance for policy. For example, BAP species updates in 2007 relied on NBMP data for priority species selection; bats were included in the UK Biodiversity Indicators in 2008 based on NBMP data. The programme provides information that helps measure outcomes for UK country biodiversity strategies and information that allows the conservation status of bats in the UK to be assessed in accordance with the Habitats Directive.

Project outputs: Annual online reporting of surveys, results and population trends. Regular publication of State of the UK's bats newsletter aimed at non-specialist audiences. Annual reporting of UK Biodiversity Indicator on bats via Defra. Internal projects and collaborative research projects with universities in recent years have also resulted in a small number of papers in peer-reviewed journals, for example Biological Conservation.

oldWeather

Authors: Philip Brohan (science lead)

Primary aim of the project: To recover historical weather observations for further use in studies of climate variability and change.

Type of project: Contributory

Brief introduction: To put today's weather into context, and to test and improve the models we use for predicting future weather and climate, we need detailed records of past weather events going back decades and centuries. Such records exist, but they are handwritten documents preserved in the world's museums and archives – and so inaccessible to science. oldWeather is recruiting volunteer researchers to read some of these documents (ship's logbooks), and to recover the weather records and historical details recorded on them.

Start date: October 2010

Current status: Active

Geographic scope: Global ocean

Routes to involvement: Website

Type of data collated: Air temperature (dry and wet bulb), sea temperature, pressure and barometer temperature, present weather, wind speed and direction. Ship location/date/events on board.

Data storage and availability: Weather data currently on website (http://blog.oldweather.org/results) and being included in the International Comprehensive Ocean-Atmosphere Dataset (http:;/icoads.noaa.gov). Ship events/historical data on http://navalhistory.net .

Quality assurance: Each transcription is done independently by three different people and results are kept only if at least two agree. Tests indicate >99% accuracy.

Training involved: Video instruction and tutorial on the website, user forum.

Partners involved: Met Office, Oxford University, Citizen Science Alliance, National Maritime Museum, US National Archives, NOAA, NavalHistory.net. Funding from Defra, JISC, NSF, and NPRB.

Number of participants: 16,400+

Successes: More than 1.6 million weather records so far recovered from Royal Navy records covering the period 1914-23, and contributed to global climate datatsets. This has substantially improved the global observational coverage for that period. The success of the original project has inspired a follow-on based in the US and wider international interest in the potential of archived climate data.

A significant secondary success is the production of detailed histories, for each of the 312 ships used in the project, on the NavalHistory.net website. oldWeather has become an exemplar for the digital humanities, and for interdisciplinary research.

Lessons Learnt: The project was developed by a collaboration between domain specialists (historical climatologists), internet experts (website and user interface designers), and community science experts; it needed all three components to be successful. The emergence of organisations like the Zooniverse is a very effective way to create such collaborations and create useful community science projects.

Policy links: Source of archived climate data.

Cost: Citizen science aspects (website, user interface, tutorials, etc.) have cost perhaps £100,000 to date.

Open Air Laboratories Network

Authors: Lucy Carter and John Tweddle, Natural History Museum

Primary aim of the project: To provide opportunities for people of all backgrounds and abilities to explore and learn about their local environments by participating in meaningful scientific research.

Type of project: Contributory – participants follow set protocols to gather data, then submit their results via an online system or by post.

Brief introduction: OPAL (**http://www.opalexplorenature.org)** is an England-wide partnership initiative led by Imperial College London. Since 2007, OPAL has designed and run six citizen science surveys each investigating a different aspect of the environment – soil, air, water, hedgerow biodiversity, climate and invertebrates in the built environment. Surveys are aimed at a public audience with no prior knowledge or experience required. Participants enter their results via a Google maps based online system where they can instantly see their results on a map and compare them to those submitted by other participants. Data are analysed by scientists at a range of academic institutions, resulting in a number of peer reviewed publications with several more in preparation.

Start date: December 2007

Current status: All surveys are ongoing

Geographic scope: England-wide

Routes to involvement: Each survey was accompanied by a media launch including television, radio and print coverage to attract participants. OPAL staff across England ran public events and carried out 'train the trainer' courses to enable community leaders and school teachers to confidently lead the surveys with their own groups. Up to 40,000 survey packs were printed and distributed for each survey (approximately half going directly to secondary schools) and all survey materials were available for download free of charge. Survey results can be submitted online or via a freepost address. One survey allowed data submission via text message, and another produced a mobile app to facilitate the submission of biological records supported by a photograph.

Data storage and availability: All data are stored within the central OPAL database at the Natural History Museum. All data will be publicly available via the NBN Gateway in due course.

Type of data collated: A wide range of data were collected across six citizen science surveys, including biological records (some supported by a photograph), soil characteristics (smell, texture, compaction, pH), water characteristics (pH, turbidity), habitat/micro-habitat features and meteorological measurements (wind speed and direction).

Quality assurance: Data validation is built into the online data entry system. A number of quality assurance methods have been built into the survey designs, and assessments of data quality have been made using online quizzes/tests, by observing participants carrying out the surveys to quantify error rates and identify common mistakes, and by comparing citizen science data with professionally collected data.

Training involved: No prior knowledge or experience was required, enabling anyone to take part. Survey materials were designed with this in mind, so full details were given and identification guides aimed at beginners were provided. A 'group leaders support pack' was produced for each survey and made available online. 'Train the trainer' sessions were run for group leaders and regional outreach staff to support the public in carrying out the survey, but the majority of participants took part with no face to face training.

Partners involved: OPAL is a partnership initiative led by Imperial College London. The fifteen partners include the Natural History Museum, University College London, Open University, Field Studies Council, University of York, University of Newcastle, University of Birmingham, University of Nottingham, University of Plymouth, University of Hertfordshire, University of Central Lancashire, National Biodiversity Network, Met Office and Royal Parks.

Number of participants: To date, over 42,500 sets of survey results have been submitted.

Successes: OPAL has engaged over 500,000 people with their local environment through local and national projects that are fun and accessible to all.

OPAL has experimented with different survey designs, levels of complexity and a variety of taxonomic groups including understudied groups such as lichens, earthworms and slugs. Survey returns have been excellent given their relative complexity and the time commitment required to take part (approximately one hour to carry out the survey plus time to enter results online).

Participation in genuine scientific research is a significant motivation for many members of the public, in particular secondary schools which are keen to involve 'real world science' and outdoor learning in their curriculum but lack the confidence and materials to do so.

The partnership approach to OPAL and the strong collaboration with voluntary natural history groups, in particular the national recording schemes and societies, has brought added value to the project by drawing in taxonomic expertise and ensuring a truly national reach.

Analysis of the data is ongoing but several peer-reviewed publications have resulted from the project with several more in preparation. Distribution maps for earthworms are now available on the NBN Gateway.

Lessons Learnt: Many more people took part in the surveys than submitted their results. Evaluation to date suggests that this is partly due to a lack of time for data submission, or a lack of confidence in the quality of their results. Over the course of the project a number of methods have been employed to increase data submission rates including making online registration optional, allowing data to be submitted via a freepost address, creating online ‘awards’ as incentives for data entry and enabling data to be submitted via text message and mobile phone app.

The number of participants a survey attracts is negatively correlated with the level of complexity and time required to take part. Elements of the surveys that required only a single observation received many more data returns than surveys with set protocols and detailed methodologies that took a significant amount of time. This represents a trade off between the benefits of gathering detailed or standardised data and the benefits of having a greater number of data points.

‘Train the trainer’ sessions proved extremely valuable in enabling more people to take part and increasing data quality by providing guidance on survey methods and boosting identification skills.

OPAL Bugs Count survey

Authors: John Tweddle and Lucy Carter, Natural History Museum

Primary aim of the project: The project has joint aims of investigating how the built environment affects the distribution and abundance of terrestrial invertebrates, whilst reconnecting local people with the nature that surrounds them.

Type of project: Contributory

Brief introduction: A participatory survey investigating how the built environment affects the distribution and abundance of different groups of invertebrates, as a contribution to scientific understanding of the ways in which urbanisation affects biodiversity. Aimed at the general public particularly primary and secondary school pupils and families, it has a joint focus on research and awareness raising. It includes 15 minute surveys of invertebrate abundance in 3 habitats within the built environment, description of habitat features and species-level recording of six taxa that are believed to be in a state of population flux, or which have poorly understood urban distributions. The survey is supported by teaching resources and a free survey pack and mobile phone app.

Start date: May 2011

Current status: Active

Geographic scope: UK, with a focus on England

Routes to involvement: Survey materials can be freely downloaded from the OPAL website. 30,000 printed survey packs have also been disseminated, over half of which have been targeted at primary and secondary schools. A third route to involvement is through face to face interaction with Natural History Museum and OPAL scientific staff at public-facing events and community-based initiatives, including train-the-trainer sessions.

Type of data collated: Quantitative, georeferenced data on gross level terrestrial invertebrate abundance and diversity in relation to habitat features. Biological record data for six individual invertebrate species. Detailed microhabitat data from urban and rural locations.

Data storage and availability: All data are stored within the central OPAL database at the Natural History Museum. Photo-supported biological record data are disseminated to national recording schemes, through which they enter the NBN Gateway.

Quality assurance: validation of data format on upload and expert verification of all species records that are supported by photographs. Accuracy of records that are not supported by photographs is estimated based upon experimental observations of identification practices and commonly made errors within different sectors of the public.

Training involved: The survey assumes no prior knowledge. It is supported by a survey pack and mobile phone App, both of which include identification guides tailored to the survey. Group leaders and teachers resources are also available to support delivery of the survey by community and schools groups, respectively.

Partners involved: Developed by the Natural History Museum with support from the OPAL partnership and six national biological recording schemes. The OPAL portfolio as a whole is led by Imperial College, London.

Number of participants: 19,500 in first 12 months of project.

Successes: Fantastic uptake so far, with elements of the survey pack downloaded >30,000 times and a large volume of data uploaded. Data for 5,400 survey sites were uploaded during the first 12 months, totalling 800,000 invertebrate sightings (pre-data cleaning). Hence, the survey succeeded in producing a very large dataset from sites that simply would not be accessible by scientists alone (e.g. gardens and school grounds). Analysis of the first year's results is currently in progress, but initial findings suggest that data quality is sufficiently accurate to allow investigation of the projects stated aims; to build a better understanding of gross-level invertebrate abundance and distribution in relation to features of the built environment and to help map the current distributions of six individual taxa. Uploaded invertebrate photographs are high enough quality to allow identification accuracy to be verified and a reasonable volume of verified species-level biological records have been generated (ca 1000).

Media interest has been extremely high – the NHM is a trusted organisation and invertebrates capture the imagination (whether we 'love' or 'hate' them). This has made the survey easy to sell to press and potential participants alike. The mobile phone App has succeeded in broadening the survey audience and currently accounts for 45 % of the photos that have been uploaded to the survey website.

Over 60 % of surveys were completed by school groups and although data quality were variable, this clearly shows the potential market for real-world science projects and data generation via the formal education sector (a cost effective, guaranteed market).

Lessons Learnt:

- Science sells: participative projects are currently highly desirable, particularly if they are led by a trusted institution.
- Participants will record less charismatic species if there is perceived to be clear scientific value in doing so.
- There is a will amongst large sectors of society to become more involved in science. OPAL-style projects can help rebuild trust and break down national environmental issues into locally relevant, achievable actions.

- Social relevance is critical to gaining involvement, whilst timely feedback is essential to reward and maintain participation.
- It is difficult to design a survey that has mass appeal to a general public audience, as opposed to a specialist membership.
- Constant promotion is necessary to maintain uptake.
- A mixed approach to project delivery works well (e.g. a combination of downloadable resources and face to face interaction), but is labour intensive.
- Face to face interaction is an effective way to build a deep understanding of data accuracy and capture feedback.
- Unless an essential component of the project, it is difficult to persuade participants to back up their observations with photographic evidence.
- It is possible to produce a technically simple mobile phone App that uploads fully verifiable biological records to a central database.
- Identification accuracy was lower for photos sent via mobile App cf. uploaded via the main data entry form on the OPAL website.
- Real-time web-based mapping and display of results is a fantastic way to instantly reward and encourage participation.
- Web upload of results represents a post-survey step many potential participants are unwilling to take. Direct upload in the field via an App can remove this barrier.

OPAL Soil and Earthworm Survey

Authors: David T. Jones & James Bone (Imperial College London & Natural History Museum)

Primary aim of the project: The OPAL Soil Centre, led by Imperial College London, has two main aims. The first is to get as many people as possible interested in the soils and earthworms in their local area. To achieve this OPAL engages local communities to help them appreciate how important soil is to society, and to understand more about the ecology of earthworms. The second aim is to recruit citizen scientists to participate in scientific research projects. Participants have been recording soil properties and collecting and identifying species of earthworms in their local environments.

Type of project: Contributory

Brief introduction: Soil is a vital and non-renewable resource, which performs many important functions. The effects of poor air and water quality are visible and obviously threatening to human health but the importance of soil is often overlooked (Bone et al, 2011).

Earthworms play a major role in the soil ecosystem. Through their feeding and tunnelling activities they drive the decomposition process, promote nutrient recycling and improve soil structure and quality. However, despite much research into their impact on soils, the geographical distribution of earthworms in the UK is still grossly under-recorded (Carpenter et al 2012, Biodiversity & Conservation, 21: 475-485). Therefore, the OPAL survey will help to get a better understanding of which species occur where, and whether they are associated with specific habitat types or soil properties.

Start date: March 2009

Current status: Active and ongoing.

Geographic scope: Primary focus on England, some wider UK coverage

Routes to involvement: Website with freely downloadable resources, workshops with community and school groups, train the trainer sessions, 45,000 hardcopy survey packs distributed, online and postal data entry

Type of data collated: Identity, abundance and geographic distribution of 12 common species of earthworms, pollution signs, physical soil properties (incl. pH, approximation of carbonate content, soil texture, smell and colour).

Data storage and availability: Available in summary form via the OPAL website, dataset also accessible through the NBN Gateway

Quality assurance:

The scientists designing and analysing data from the OPAL Soil and Earthworm survey sought to address concerns over data quality in two ways; (1) by cleaning the survey data, and (2) by comparing the data with existing knowledge.

The cleaning of data was designed into the survey from the outset by the inclusion of a number of 'cross checks' when participants submit data to the website. Survey submissions were checked for location accuracy by comparing postcode and the location of the survey given by participants on a map. Multiple identical surveys from one area were treated as duplicates, and where all fields were identical they were flagged as such. Records were also flagged where they were outside England, which was the geographical scope of the survey.

In England there have been a number of established soil surveys, and there is a good geographical understanding of land cover. Selected responses (including land use, soil texture and topsoil pH) from the OPAL Soil and Earthworm Survey were compared with existing datasets to give an indication of the accuracy of the survey data. This showed a generally good comparison to these existing datasets. Importantly the Soil and Earthworm Survey showed the same broad scale patterns as is known to be present for a number of soil properties, particularly topsoil pH.

The quality of the earthworm identifications was assessed by direct observations of participants as they did the survey at a number of public events. Specimens were collected after they had been identified and subsequently checked by the OPAL earthworm specialist.

Training involved: Train the trainer sessions and freely downloadable trainer/group leaders pack, downloadable and printed instruction pack and earthworm identification guide

Partners involved: Imperial College London, Natural History Museum, Environment Agency, British Geological Survey, Field Studies Council

Number of participants:

45,000 Soil & Earthworm survey packs produced and distributed.

7,059 downloads of the online version of the survey pack.

As of 24th August 2012 the number of survey results submitted to the OPAL website = 4,196.

Successes: Earthworms are a great "hook" with which to engage both children and adults. While being ubiquitous and easy to find, they are still unfamiliar enough to most people to provoke many questions. At outreach events, earthworms have proven to be an effective educational tool – people are fascinated when they look at an earthworm through a microscope. This "hands on" experience will usually initiate a wide range of discussions. For example, children's questions will often lead to them learning about animal movement, decomposition and composting, food chains and other life in the soil, whereas conversations with adults often turn to subjects such as soil biodiversity, soil erosion, nutrient recycling, carbon storage, climate change and habitat conservation.

Land use types such as gardens have proved difficult habitats to sample in existing soil surveys due to problems with access. Working directly with the public the Soil Centre received around 1000 returns from gardens across the country (up until June 2012). This gave new insights into this habitat which has often been altered by landscaping, gardening and building activities.

Lessons Learnt: Earthworm identification usually requires specimens to be preserved, examined with a microscope and compared with a technical identification key. This was not a realistic option in the OPAL Soil and Earthworm survey as most people do not have access to a microscope or the confidence to use a technical key. Therefore, we designed a user-friendly guide to the ten commonest species of British earthworms (Jones & Lowe, 2009). This guide relied on a simple set of easily-observed characters, including colour, size and presence or absence of the male pore. A study of participants' identifications showed reasonably good levels of identification overall. However, (1) children had higher rates of misidentifications compared with adults, and (2) some species were "easier" to identify than others (DT Jones in prep.). This reflects the obvious truth that live, wriggling earthworms can be difficult to identify to species. To guarantee the highest possible rates of correct identification, all specimens would need to be verified by an earthworm specialist. But at the the start of the project it was considered that the logistics involved in gathering and processing specimens from the anticipated number of surveys would be prohibitively expensive.

Soil is very complex and varies a lot over small distances. Correspondingly many properties of soil are complicated to measure, requiring extensive skill and training and expensive equipment. This does not lend itself well to citizen science projects – instead methods should be developed to collect information on indicators of soil quality that can be successfully used by members of the public who have received minimal training.

Due to the heterogeneous nature of soils, and variability in data collected by citizen scientists, most benefit can come from evaluating data at a macroscopic level. This has been shown from analysis of data from the Soil and Earthworm Survey to demonstrate trends across the country, which can be used to inform more detailed investigation (Bone et al, 2012b).

Policy relevance: The protection of soil has become a significant political as well as environmental objective, and there has been pressure for improvements in soil quality as has been seen for water and air. The vision for England's soils was outlined in the Natural Environment White Paper (June 2011), which set a clear target that by 2030 England's soils will be managed sustainably and degradation threats tackled successfully. At a European level the draft EU Soil Framework Directive was introduced by the European Commission in 2006 after being proposed in an EU Thematic Strategy on Soil Protection; this seeks to harmonise and raise the level of soil protection across the EU. A greater understanding of the soil system and soil biodiversity is needed to provide evidence for such policies. The OPAL Soil and Earthworm Survey provides a large amount of information on a number of potential indicators of soil quality from across England. This data could be used to highlight areas of the country where further investigation is needed.

Project outputs:

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Bone, J.; Head, M.K., Jones, D.T., Barraclough, D., Archer, M., Scheib, C., Flight, D., Eggleton, P., Voulvoulis, N. (2010) Soil Quality Assessment under Emerging Regulatory Requirements. Environment International, 36 (6). 609-622

Bone, J., Head, M., Jones, D.T., Barraclough, D., Archer, M., Scheib, C., Flight, D., Eggleton, P., Voulvoulis, N. (2011) From Chemical Risk Assessment to Environmental Quality Management: The Challenge for Soil Protection. Environmental Science and Technology, Environmental Policy: Past, Present, and Future Special Issue, 45 (1), 104-110

Bone, J., Barraclough, D., Eggleton, P., Head, M., Jones, D.T., Voulvoulis, N. (2012a In Press) Prioritising Soil Quality Assessment through The Screening of Sites: The Use of Publicly Collected Data. Land Degradation and Development. In Press Accepted

Bone, J., Archer, M., Barraclough, D., Eggleton, P., Flight, D., Head, M., Jones, D.T., Scheib, C., Voulvoulis, N. (2012b) Public participation in soil surveys: lessons from a pilot study in England. Environmental Science and Technology, 46 (7), 3687–3696

Jones, D.T. & Lowe, C.N. (2009). Key to Common British Earthworms. OPAL Soil Centre, Imperial College London, UK.

Open Farm Sunday Pollinator Survey

Authors: Annabel Shackleton (LEAF) and Helen Roy (CEH)

Primary aim of the project: The two key aims of the project were: (1) to collate records on the types and numbers of insects visiting flowers (proxy for pollinators) from farms on Open Farm Sunday (17th June 2012) taking part in a systematic survey as a measure of biodiversity, and together with much wider datasets, to use the patterns that emerge to try and understand how pollinators are responding to changes in our environment and, in turn, to support farmers to increase crop production; (2) to encourage the public to get actively involved in scientifically recording wildlife.

Type of project: Co-created and contributory

Brief introduction: The project set out to engage the public in a scientifically credible survey of pollinators on farms participating in the seventh Open Farm Sunday (OFS) on 17th June 2012. OFS is widely recognised as the farming industry's annual open day - since 2006 almost one million visitors have attended OFS events across Britain to discover the link between food, farming and nature. The initial concept of the OFS Pollinator Survey was developed and implemented by the NERC Centre for Ecology and Hydrology in partnership with Syngenta, LEAF (Linking Environment And Farming – the organisers of OFS) and other leading scientists. Farmers across Britain were invited to host the Pollinator Survey during OFS in which the public were invited to count the number and type of insects that visit flowers in two adjacent habitats on the farm (crop and non-crop) over five minutes. Farmers were given detailed guidelines on suitable locations for the survey and how to run it. As each OFS event is unique, it was up to the host farmer when and how the pollinator survey was made available to their visitors. At some events the survey was a feature of the farm tour; at other events it was one of many activities available for visitors for the duration of the event.

A further activity was developed to run alongside the Pollinator Survey which essentially recorded presence or absence of five common insects on farms: Discover Pollinators.

Current status: Complete, but partners are exploring the opportunity to repeat the survey in 2013 and beyond.

Geographic scope: Available to farmers across UK who registered to host an OFS event on 17th June 2012. Data was recorded and submitted to CEH by 33 farms, well spread across England from Cornwall to Northumberland, plus one farm in South Wales.

Routes to involvement: Farms wishing to host the Pollinator Survey had to register for OFS online and tick a box to say they wanted to participate in the Pollinator Survey. Farmers also had to request the printed recording sheets through the online resources ordering system – 35,000 recording sheets and 500 posters were distributed.

The pollinator survey was promoted to all 1000+ past OFS host farmers, farms that registered to open on 17th June 2012, farmers who attended the 17 Open Farm Sunday workshops. Additionally a range of communication methods (press releases, Twitter, website, e-newsletters, etc) contributed to promotion across the farming industry. Features were included within Farmers Weekly, Farmers Guardian and other publications.

Ecologists and other scientists working at the NERC Centre for Ecology & Hydrology and Syngenta volunteered to help and attended a training event or were given one to one training by telephone/email.

Type of data collated: Counts of insect groups (ladybirds, other beetles, ants, flies, bees, butterflies and moths). Weather conditions (sun, cloud cover, wind, precipitation). For each of the two survey sites: type of habitat; amount of flower cover; number of ladybirds, beetles, ants, flies, butterflies, bees, other. Visitors were asked to make predictions about likely findings and comment on their actual findings.

Data storage and availability: Data was entered through the OFS website www.farmsunday.org, into Indicia, hosted by the NERC Centre for Ecology & Hydrology.

Quality assurance: 20 host farms were supported by over 40 trained volunteers. The trained volunteers conducted the survey at the beginning and end of the event to provide a rigorous dataset. The volunteer ecologists/scientists were on hand at these focus farm events to guide visitors through the process and conduct the survey at the beginning and end of the event to provide a rigorous dataset.

Training involved: Mike Edwards, professional ecologist, presented the Pollinator Survey to the team of OFS Regional Co-ordinators at their annual training event. 190 host farmers were given a brief overview of the Pollinator Survey during the 17 OFS workshops held across Britain in February and May 2012. 20 of the volunteer ecologists who helped with the survey on farms attended a training event including training in the field. Volunteer ecologists who were unable to attend this event were given one to one guidance by the lead scientists either in person, on the telephone or by e-mail. Full guidance notes and podcasts were developed for host farmers and volunteers and available to all via the website www.farmsunday.org.

Partners involved: Syngenta, NERC Centre for Ecology & Hydrology, LEAF (Linking Environment And Farming) and other leading experts.

Number of participants: In total 335 farms registered to host an OFS event in 2012. Of these, 110 farms requested to host the Pollinator Survey and were sent recording sheets and posters.

33 farms across 21 counties submitted data to the Pollinator Survey. 556 surveys were completed, some families worked as a team to record the insects so the exact number of participants is unknown. Over 40 volunteer ecologists provided expert support on the day.

Successes: The level of participation of farms and people was inspirational, and provided a large dataset with information from across the country. From the data it is clear that certain habitats are more attractive to insects and it is encouraging that these include crops.

- 33 farms across 21 counties took part in the Pollinator Survey, sampling 11 different habitats
- 15,046 insects were recorded in total by 556 participants
- Over 40 volunteer scientists helped on farm
- Extensive media coverage: in total there were 62 mentions of the Pollinator Survey in consumer, regional, national and trade media – this includes 7 mentions in national news and 5 mentions in national broadcast media.
- Website: 663 unique page views to the information on the OFS website.
- Host farmer feedback is very positive that they were delighted to be able to offer the pollinator survey as a new activity on their farm and great to have something that visitors could get involved in.

Lessons Learnt:

- Linking in with OFS was a great way to involve the public in citizen science and get a good dataset from across a widespread geographic area.
- Pollinator Survey form needs to be simplified and ideally constrained to 2 sides of A4. The identification grid could be a separate resource to take home but is useful for talking to groups and explaining identification features.
- Some younger children were enthusiastic about counting the insects on the flowers but the weather and habitat sections were too onerous for them. There needs to be flexibility in this approach so that some groups complete the entire form while others have the weather and habitat completed rapidly for them before commencing the counting component of the survey (with help!).
- The survey worked best where there was a dedicated information point eg a couple of tables with posters, forms and volunteers to explain the activity
- The visitors would have benefited from enhanced briefing and this could be delivered through timetabled “Ask the expert Q & A” or short talks to brief large groups.
- Two ecologists at the field site is adequate but support is required to guide visitors to the survey site and discuss the survey on the way (nearly all the field sites were located away from the

“main event”). So ideally at least 3 people per farm dedicated solely to the survey (2 ecologists + 1).

- Name badges and or polo shirts would be useful to identify the volunteers.

Policy relevance: The OFS Pollinator Survey could become part of a broad Pollinator Monitoring Network underpinning policy.

Project outputs: Many resources including dedicated web pages (http://www.farmsunday.org/ofs12b/open/PollinatorSurvey.eb), cartoon describing the survey (http://www.farmsunday.org/ofs12b/visit/Pollinator.eb), regular blogs (http://cehsciencenews.blogspot.co.uk/2012/06/pollinators-public-and-putting-your-msc.html). Additional outputs include masters thesis, peer-reviewed publication (in prep.), considerable media coverage (OFS press office incorporated the pollinator survey into media activity and extensive coverage promoting the survey to the public was achieved across national and regional media in the run up to 17th June 2012).

Predatory Bird Monitoring Scheme (PBMS)

Authors: Richard Shore (PBMS – Principle investigator) and Lee Walker (PBMS – coordinator)

Primary aim of the project: To detect and quantify current and emerging chemical threats to the environment by monitoring the concentrations of contaminants of concern in bird carcasses and eggs.

Type of project: Contributory

Brief introduction: The Predatory Bird Monitoring Scheme (PBMS – http://pbms.ceh.ac.uk/) is a long-term, national monitoring scheme that quantifies the concentrations of contaminants in the livers and eggs of selected species of predatory and fish-eating birds in Britain. We monitor the levels of contaminants to determine how and why they vary between species and regions, how they are changing over time, the effects they may have, and the effectiveness of mitigation measures. Carcasses of dead birds of prey are submitted to the PBMS principally by members of the public. Addled & deserted eggs are submitted by licensed volunteers.

Start date: 1962

Current status: Active

Geographic scope: UK

Routes to involvement (e.g. website, app, workshops etc): Website, Facebook, e-mail, talks, peer-reviewed publications, and reports.

Type of data collated: The scheme generates contaminant concentrations in the tissues and eggs of predatory birds, provenance data (location& date found, etc.), and macroscopic observations from examination of the bird.

Data storage and availability: Data available through CEH Information Gateway. Reports can be downloaded from the NERC Open Research Archive (NORA - http://nora.nerc.ac.uk/)

Quality assurance: examination and analysis of samples carried out by experts. Provenance information (inc. location) provided member of public but cross-checked by team members.

Training involved: No training required for submission of carcasses. Taking of addled & deserted eggs from predatory bird eggs should only be carried out by an individual licensed by the appropriate authority (CCW, SNH or NE).

Partners involved: The Scheme is run by the NERC Centre for Ecology & Hydrology (CEH) and is funded jointly by NERC, Natural England, the Environment Agency (EA), the Campaign for Responsible Rodenticide Use (CRRU) and the Royal Society for the Protection of Birds (RSPB).

Number of participants: 300 to 400 per year.

Successes: Results from the PBMS have informed regulators, academics and Non-government organisations for over 40 years. It was instrumental in demonstrating the success of mitigation measures for organochlorine insecticides and continues to be used to monitor chemicals of concern. Recent highlights include a demonstration of how levels of brominated flame retardants in the eggs of northern gannets, a marine off-shore predator, have responded to increased fire-regulations and latterly restrictions on the use of these compounds (Cross *et al.* 2012). The PBMS has generated a unique tissue archive used to study chemical fate and behaviour, to trial new monitoring, and for a wide range of conservation-related studies. The PBMS was the lead partner in forming the Wildlife Disease & Contaminant Monitoring and Surveillance network (WILDCOMS; www.wildcoms.org.uk), a new collaborative network formed between the various UK surveillance schemes that monitor disease and contaminants in vertebrate wildlife.

Lessons Learnt: Communication and feedback needs to be tailored to different stakeholder groups in order to engage with all the individuals and organisations that can contribute to a successful citizen science project.

Policy links: The PBMS is the only wildlife exposure monitoring programme that covers marine, freshwater and terrestrial habitats at a UK scale. Its work provides underpinning scientific evidence that informs government policy. The PBMS contributes to national/international monitoring and risk assessment programmes and provides a scientific evidence base to inform regulatory decisions. For more information see the Policy Relevance page on our website (http://pbms.ceh.ac.uk/).

Cost: Annual costs of running the scheme are approximately £180,000

Recording Invasive Species Counts

Authors: Peter Brown (Anglia Ruskin University), Mandy Henshall (NBN Trust) and Helen Roy (CEH)

Primary aim of the project: To raise awareness of invasive non-native species and the risks that they present; to engage the public in monitoring a small suite of non-native animals and plants.

Type of project: Contributory

Brief introduction: The UK has over 5000 non-native species, a proportion of which are invasive. The Convention on Biological Diversity (CBD) recognises that invasive alien species (IAS) are one of the major threats to biodiversity. Surveillance and monitoring are considered to be critical. Countries across Europe are developing national databases on IAS threats and delivering these through web-based portals. Public engagement is a critical element of surveillance and monitoring of IAS. The charismatic harlequin ladybird has been considered as a model species in terms of engaging the public in monitoring, so the Harlequin Ladybird Survey was used as a template for the RISC project.

Start date: Project work started Sept 2008; project launch to public was 22 March 2010.

Current status: Active and ongoing.

Geographic scope: UK

Routes to involvement: Website (www.nonnativespecies.org/recording), talks to promote project, national media coverage achieved.

Type of data collated: Presence, abundance, habitat data, optional photograph of species for expert verification encouraged.

Data storage and availability: CEH Indicia / NBN Gateway

Quality assurance: Data validated by expert, aided by species photograph when provided.

Training involved: None

Partners involved: Defra (funder), CEH, NBN, Anglia Ruskin University, GB Non-native Species Secretariat, national UK recording schemes for the selected species.

Number of participants: 633 (1166 records)

Successes: Successful set up of a sustainable ongoing project managed at low cost. The project launched with six species and this has grown to 19. Further species can be added with low amounts of additional (IT) work.

Development of an online recording form that is both user-friendly and provides clear, easily managed data. This project was used as an early test of Indicia software.

Involvement of national recording scheme volunteer experts to verify the data received.

National and regional media coverage was achieved, particularly at project launch. This included television (Anglia TV), radio (BBC Radio Four, BBC Radio Five Live, BBC Radio Scotland) and national press (Guardian, Daily Mail, BBC Wildlife, BBC Country File).

Lessons Learnt: A relatively low number of records have been received. On the strength of the Harlequin Ladybird Survey it was hoped that engagement of the public with RISC would be more successful. However, the harlequin ladybird has many features that have helped it achieve high level public engagement. For example: the harlequin is easy to spot inside houses and gardens and is common in many urban areas; it is relatively easy to identify; it is easy to photograph; it spread quickly to most parts of England and Wales; it is a colourful and attractive species; the public likes ladybirds; the media has maintained a high level of interest in the project for nine years!

Many of the above achievements of the harlequin project were facilitated by a lot of work by the recording scheme organisers and for the first two years by a fully funded Project Officer position. A similar Project Officer role for RISC could therefore have been beneficial.

A leaflet outlining the project was developed (available online as a PDF), but only small numbers were printed and distributed. Budget for a large and well-distributed print run of the leaflet may have been highly beneficial.

A further lesson involves the RISC website and URL. Firstly, for cost and time reasons the development work on the RISC webpages (as opposed to the online recording form) was kept minimalist and carried out in-house. The pages are thus functional and very good value for money, but design-wise could be improved. Secondly, the webpages are rather hidden away in the GB Non-native Species Secretariat site. A catchier URL and more prominent website would have helped.

Policy relevance: Component of UK non-native species surveillance and monitoring.

Project outputs: Conference presentations: NBN Conference 2009; British Ecological Society workshop 2010; Robson meeting 2010; plus mentioned at various international conferences (e.g. in Italy, Belgium & Russia). Newsletters: articles in NBN News, BSBI News, Elements (Defra magazine), In Practice (Institute of Ecology and Environmental Management), Catalyst (GCSE schools magazine), NERC Planet Earth online blog. Species factsheets. Webpages and online recording forms.

Rothamsted Insect Survey (RIS) Light Trap Network

Authors: Chris Shortall (Administrator – RIS Light Trap Network)

Primary aim of the project: To collect data on the distribution and population trends of macromoths across the British Isles

Type of project: Contributory

Brief introduction: Research in the 1930s and 40s using a standardised moth trap resulted in seminal papers in the fields of moth biology and diversity. L.R. Taylor later resurrected this trap in the late 1950s with alarming results - there had been an overall decline during the 1950s of about 70% in the total number of larger moths. This led to the inception, in 1964, of the RIS Light Trap Network in order to monitor moth populations more widely to understand their temporal and spatial dynamics. Volunteers were enlisted to run traps throughout Britain and by 1968 there was a good national coverage, by 2012 564 sites had been sampled. Eighty-four traps are currently running.

Start date: 1964

Current status: Active

Geographic scope: British Isles, some traps elsewhere in Europe.

Routes to involvement: Contact with Rothamsted, weblog created in 2012, articles in the entomological press at regular intervals generate interest.

Type of data collated: Species abundance, some data on common colour forms of certain species.

Data storage and availability: New SQL database currently in development, all data freely available to interested parties.

Quality assurance: Identifiers trained to a good standard on recruitment. Traps are standardised to ensure data homogeneity across sites and years.

Training involved: New identifiers trained in a mentorship scheme by other volunteers. Training could take up to two years depending on level of experience at the outset. Operators are trained in the operation of traps.

Partners involved: The continuing, long-term research of the Rothamsted Insect Survey is supported by the UK Biotechnology and Biological Sciences Research Council (BBSRC), through National Capability funding. We are also grateful to the Lawes Agricultural Trust for continued support.

Number of participants: 84 operators, 16 sites self-identified, 20 identifiers cover the rest.

Successes: Approximately 12 million records for moths are available. The RIS moth data have been widely used in research over the years and at the last count well over 600 publications have made use of it in one way or another.

The first detailed study of a single species using RIS data was of the Garden Tiger *Arctia caja*, a species once regarded as common and widespread. Analysis confirmed that not only are there 30% fewer RIS sites recording the species now than 30 years ago but even at inhabited sites there has been a 30% decline in abundance.

Analysing records over the 35 year period from 1968 to 2002, and using very strict criteria for site and species inclusion to ensure the validity of the results, it has been possible to estimate population change for 337 species of macro-moth. The percentage of species with >10% decreases in five years (54%) was more than double those with >10% increases in five years (22%) and summed across all species macro-moth abundance has declined by almost a third over the 35 year period. However, it is clear that declines are not uniform across Britain with the strongest decline in the south, particularly the south-east, and the fewest declines in the north. In fact, overall total moth abundance in the north has remained fairly stable with species in decline being balanced out by those increasing. At the species level there is particular cause for concern. Just over 20% (71) of the 337 species are declining at rates greater than 3.5% per year, a rate which is generally regarded as cause for serious conservation concern.

Lessons Learnt: It is fortunate that there are so many members of the public with an interest and expertise in moths who are willing to contribute to the gathering of long-term standardised data. The motive of most volunteers is likely to be to increase understanding of moth dynamics in order to help identify causes of declines and hence inform mitigation policies. In order to keep volunteers on board it is essential to communicate with them regularly. Until recently this was largely through an annual newsletter, site visits from a staff member approximately every three years and responses to individual queries and requests for data. We have recently started a blog to provide instant access to news of interesting findings and operational issues. We have also recently instigated a certificate of appreciation for long service which we plan to issue every five years. This seems to be going down very well. Staff cuts have meant that site visits are no longer possible, making other methods of keeping our volunteers in touch extremely important.

Policy links: The impacts of climate change and land management on biodiversity and the ecosystem services it provides are a key national and international concern. A recent book `Silent Summer' highlights the state of wildlife in Britain and Ireland and data from the light trap network forms a crucial contribution in charting long-term changes and suggesting testable hypotheses as to their cause. The light trap network provided the evidence of rapid moth decline that is likely to be associated with environmental quality. We have collaborated with many other holders of long-term datasets on a wide range of organisms to examine changes in phenology and abundance over a 30 year period. This has led to the most comprehensive standardised study on seasonal advance to date, which concluded that the rate of advance in phenology is increasing and that lower trophic levels are advancing faster than higher trophic levels, leading to risks of inter-trophic asynchrony and disruptions to ecosystem functioning.

Cost: Approximately £70,000 per year. Volunteer input is worth around ten times this amount.

The Shore Thing Project

Author: Fiona Crouch (Project Officer - Marlin)

Primary aim of the project: To generate records of marine wildlife by facilitating intertidal biological surveys at sites around the British Isles, and to make the results available to all on the Internet. In addition we aim to raise awareness of marine conservation amongst the participants and the wider community".

Type of project Contributory = people submit data to an institutionally-controlled project;

Brief introduction: The Shore Thing Project originated from a four year study on the impacts of climate change, in particular rising sea temperatures, on a number of rocky shore species. Scientists found that southern species were moving further north and east and northern species were retreating further north. Monitoring such changes requires long term data and a lot of people surveying rocky shores. Our aim is to encourage students (Higher/undergrads) and community groups from all over the UK to monitor their local rocky shore recording the abundance of our carefully selected 22 climate change indicators and non-native species. The survey is divided into two parts; a transect survey followed by a 20 minute timed species search. Participants then upload their data on to the project website and send their forms back to us so we can verify the data. The times species search data is then verified before being made available to the wider community via NBN.

Start date: April 2006

Current status: Ongoing

Geographic scope: UK

Routes to involvement: Through the project website, community groups contacted by the Project Officer, schools and public events.

Type of data collated: Abundance scale which includes absence.

Data storage and availability: All timed species search data is available through NBN and all invalidated data is available for download from the project website.

Quality assurance: Where possible groups are supported by an ecologist. Timed species search data goes through a rigorous validation process being checked by at least two experts.

Training involved: Training courses are organised around the country for volunteers, teachers and ecologists.

Partners involved: Funding partners are SNH, CCW, NE and the MBA**.** Others include: Field Studies Centres, St. Abbs and Eyemouth VMR, Oakley Intertidal, Keep Wales Tidy..........

Number of participants: Approximately 3,000 to date**.**

Successes: Total of 35,074 records. 25,780 from the transect surveys and 9,294 from the timed species search.

As the data is made available to the wider community via NBN participants really feel that they are involved in 'REAL' science. They also gain an appreciation of the marine environment on their doorstep and the need to conserve it. The training has proved invaluable in getting people involved, giving participants the confidence to organise their own surveys.

The different components of the project covers may aspects of the science curriculum and will be particularly useful in teaching aspects of the new Scottish Curriculum of Excellence. The production of education resources and support material has been an additional benefit of the project. The Shore thing has also been used by other organisation as a model to develop similar rocky shore surveys.

The bi-annual newsletter and website is an important and valuable way of providing feedback to participants.

Lessons Learnt: Surveys should take place on a low spring tide but unfortunately they do not always occur at a convenient time of the day for students especially to conduct surveys. For example in Kent low springs are early in the morning and late evening. The number of surveys that can be conducted are limited by the number of good tides. Students in particular have a very limited knowledge (if any) of rocky shore ecology even at A level. Although the project has been designed to be sustainable there needs to be a project officer in post to encourage groups to conduct surveys.

Policy relevance: Getting people involved in biological recording. Provides policy-makers with information on the biodiversity of rocky shores around the UK and the potential impacts of climate change on the marine environment.

Project outputs: Education resources, Bi-annual newsletter, field guides/survey resources.

United Kingdom Butterfly Monitoring Scheme (UKBMS)

Author: Ian Middlebrook (Butterfly Monitoring Co-ordinator – Butterfly Conservation) and David Roy (Head of Biological Records Centre – Centre for Ecology & Hydrology)

Primary aim of the project: To assess the status and trends of UK butterfly populations for conservation, research and quality of life.

Type of project: Contributory

Brief introduction: Butterflies are uniquely placed amongst British terrestrial insects to act as indicators of the state of the environment. Changes in the abundance of butterflies throughout the United Kingdom have been monitored through transects since 1976. Over the past 36 years, the huge network of recorders has collectively made around a quarter of a million weekly visits to almost 2000 different sites, walking over half a million km and counting over 16 million butterflies. The UKBMS is based on a well-established and enjoyable recording method and has produced important insights into almost all aspects of butterfly ecology.

Start date: April 1976 following pilot years in 1973, 1974 and 1975

Current status: Ongoing

Geographic scope: UK (with some additional data from Isle of Man and Channel Isles)

Routes to involvement: Most contributors to the monitoring scheme have already developed identification skills through recording, so have some previous involvement, either through the Butterfly Conservation charity or through the sites that they are involved with. There is information about the Scheme and the transect methodology on the UKBMS website. There is support for new recruits through BC staff, and also a network of volunteer transect co-ordinators in each local BC branch.

Type of data collated: Abundance data - mostly (preferably) weekly counts from fixed transect routes. Some additional counts from other validated methods (e.g. timed counts of adults, egg/larval couts) are also accepted.

Data storage and availability: Free Software (Transect Walker) is supplied for volunteers to store and analyse their own data, and this also aids national data collation each year. Full scheme data are held on a database at CEH, and summary data for all sites/species is openly available through the UKBMS website (www.ukbms.org.uk). More detailed datasets are available on request. Summary distribution data made available on the NBN Gateway, via inclusion with Butterflies for the New Millenium datasets.

Quality assurance: The transect method has been validated to record a consistent proportion of each population. Data submitted each year is validated centrally against expected flight periods and ranges with possible recording or data entry errors being referred back to recorders and corrected. We are also in the process of validating volunteer data against professionals by shadow walking their transects.

Training involved: Local branches of butterfly conservation provide several field trips and training days to assist with butterfly identification. National and Regional Staff of Butterfly Conservation provide more detailed workshops covering the monitoring methodologies across most regions each year. Other new recruits to transect monitoring learn 'on the job' by shadowing more experienced volunteers in their area.

Partners involved: Managed as a partnership between CEH and Butterfly Conservation, with funding from a consortium of government agencies co-ordinated by JNCC and currently (2011-2014) including Defra, Countryside Council for Wales, Natural England, Northern Ireland Environment Agency, Forestry Commission and Scottish Natural Heritage. Other organisations such as local authorities, National Trust, RSPB, Wildlife Trusts and other voluntary organisations are actively involved through the provision of data from their Nature Reserves.

Number of participants: circa 1500 each year and at least 4000 since the scheme began.

Successes: The scheme has grown enormously since its early days in the mid 70s. 34 sites were monitored in 1976 and now data is received from more than 1000 sites each year. This expansion has resulted in, what is now, one of the most extensive and well-used invertebrate datasets in the world. The success of butterfly monitoring in the UK has also had the effect of promoting butterfly monitoring elsewhere, with several successful schemes subsequently being set up in other countries around the World. This is especially true in Europe, where the UKBMS now contributed to pan-European butterfly indicators for the European Parliament.

At a more local level, the fact that the transect methodology is based on collecting data at fixed individual sites means that the butterfly trends have the potential to be used to influence habitat management at those sites. We recently carried out a questionnaire to find out whether that was the case and found a good level of communication between our volunteers and site staff, with 91% of site managers reporting that they regularly receive the butterfly monitoring data and 83% stating that those data contribute to management decisions, either formally or informally. This indicates that the conservation of butterflies has become a higher priority for land managers as a result of the success of this scheme.

4540152 records; 265971 visits; 17589847 individual butterflies (and a few moths) counted

Lessons Learnt: Maintaining a network of 1000+ sites, combined with the intensive demands of monitoring weekly for 6 months of the year, could be a massive job. But the enthusiasm of volunteers to plough on with the project, often with limited need for support, is a constant source of surprise. Where and when more support is needed, our group of local transect co-ordinators (about 30 around the country) are invaluable in dealing with all routine problems, so that staff are free to deal with more technical aspects of supporting the network.

The intensive demands of the transect method does have some drawbacks in retaining new volunteers, who perhaps don't always appreciate the full extent/impact of the weekly commitment until they have tried it for a year. This can result in a proportion of new transects falling by the wayside after a year or two, or failing to produce sufficient data to be of great value. This does mean that we constantly need to recruit new transects/volunteers in order to maintain our high monitoring levels. However, despite this, the scheme is still growing year-by-year, perhaps aided by strong central support and improved wider publicity for the outputs of the scheme.

As the scheme grew, and CEH and BC datasets were combined a few years ago, it became clear that data processing could become unmanageable unless volunteers could supply data in a standardised format. This is when bespoke software (Transect Walker) was developed in order to aid the data collation process. The software includes several feedback features by way of charts and tables, and this has encouraged its take-up by many volunteers. We now receive 98% of our data in this format, although in some branches we do find that most data is entered by a small handful of people who are familiar with the software. The use of software in itself also generates a need for technical support from staff and co-ordinators.

The fact that transects are set up at sites selected by the volunteers does mean that most monitored sites are 'good' butterfly sites, often on nature reserves or other protected areas, which leads to the possibility that our results do not necessarily reflect what is happening across the wider countryside. This failing has been address in recent years by the addition of a less-intensive Wider-Countryside Butterfly Survey (see separate submission).

Policy relevance: The UKBMS produces Headline Government Indicators on the state of UK butterflies each year. Our comprehensive dataset also allows us to assess the impacts of habitat change, climate change and the progress of government policy initiatives such as the UK Biodiversity Action Plan, Agri-Environment Schemes and the condition of protected areas such as SSSIs**.**

Project outputs: Feedback is provided to volunteers and Site Managers through a detailed Annual Report, and there is also a National Recorders' Meeting held each year before the start of the butterfly season. Data from the Scheme are used in a wide range of analyses, which result in dozens of scientific research papers each year. The Scheme also gains good national publicity at regular intervals.

UK Ladybird Survey

Authors: Helen Roy and Peter Brown (UK Ladybird Survey – volunteer scheme organisers)

Primary aim of the project: To collect & validate data on the distribution of ladybirds across the UK

Type of project: Contributory

Brief introduction: The long tradition of biological recording in Britain led to the establishment, in 1964, of the Biological Records Centre (BRC - www.brc.ac.uk). BRC (within the Centre for Ecology & Hydrology) receives data from over 80 national recording schemes for lower and higher plants, invertebrates and vertebrates, and the Coccinellidae Recording Scheme is one such scheme. Launched in 1971, it collates and analyses records of ladybird species found in Britain and Ireland, and maps their distributions.

Start date: 1971 (on-line from 2005)

Current status (e.g. active and ongoing or complete): Active

Geographic scope: UK

Routes to involvement: Website (with online recording), e-mail, Twitter, workshops, BioBlitzes, talks and publications.

Type of data collated: Species, presence/absence (often abundance), life stage, colour form, habitat, behaviour notes.

Data storage and availability: Data available through NBN Gateway but also with species information through www.ladybird-survey.org

Quality assurance: species validated by expert and automatic checks for date and locality.

Training involved: information available through the website, including PDFs of basic identification charts, feedback provided through e-mail for every record received with a photograph, workshops available annually. Systematic survey methods available as an option.

Partners involved: Biological Records Centre (NERC and JNCC). Funding for the first two years of the on-line survey provided from Defra through NBN Trust.

Number of participants: >11 000

Successes: More than 100 000 verified records received, providing an excellent resource for research. There have been many publications from the survey including a recent analysis of distribution trends pre and post arrival of the non-native harlequin ladybird (Roy et al. 2012) and the first atlas of ladybirds (Roy et al. 2011). A further collaborative study with US ladybird surveys has demonstrated the value of verification for ladybird records received through public participation (Gardiner et al. in press). The Harlequin Ladybird Survey (a component of the UK Ladybird Survey) demonstrated the effectiveness of involving people in tracking the spread of a non-native species (Fig. 1) and was used as a model for Recording Invasive Species Counts (RISC - www.nonnativespecies.org/recording) and the on-line system developed for Defra which receives information on non-native species of particular concern (alert species).

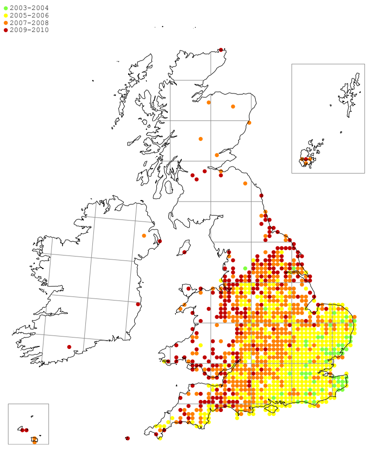

Figure 1. Spread of the harlequin ladybird (2003-2010)

Lessons Learnt: Communication and feedback using a diverse range of methods (national and regional press, website, Twitter, publications, talks, workshops, exhibitions) have been critical for ensuring continued contribution to the UK Ladybird Survey. Collaboration with both data users and data providers has also been extremely important. Production of high quality resources such as the field chart for identification of adult ladybirds through the FSC (Majerus et al. 2006) has assisted the survey. A new field chart for identification of larvae will be available later this year (Brown et al. in press) and additionally a revised addition of the Naturalist Handbook “Ladybirds” will be published in October 2012 (Roy et al. in press). Engaging the public to provide repeat survey data from the same sites over time (i.e. in a similar way to Butterfly Monitoring Scheme) has been a challenge with limited uptake to a more systematic approach.

Policy links: Harlequin Ladybird Survey used as a model for RISC and Alert systems (on-line recording for non-native species). Additional research assessing the mechanisms underpinning the spread of this species could inform risk assessment.

UK Mammal Atlas

Authors: Louise Sleeman (Atlas Campaigner) and Marina Pacheco (Mammal Society CEO)

Primary aim of the project: To collate records of all mammals across the British Isles for the publication of a UK Mammal Atlas.

Type of project: Contributory

Brief introduction: The Mammal Society was established in 1954 and is dedicated to the conservation of British mammals. Records of British mammal numbers and distribution are markedly insufficient, meaning that we are unable to construct conservation plans that we suspect are needed for many species. We have therefore embarked on a project to publish an updated National Mammal Atlas for the British Isles, by cooperating with mammal organisations across the UK as well as the public to bring together records. Our atlas will provide a baseline so that future changes can be monitored and informed decisions can be made for appropriate conservation strategies.

Start date: 2011 (collecting data from 2000-2015)

Current status: Active and ongoing

Geographic scope: British Isles (data sharing agreement with Ireland)

Routes to involvement: Website (online recording), Facebook, Twitter, e-mail, training courses, media, e-bulletins and membership magazine.

Type of data collated: Species presence/absence and abundance, habitat type.

Data storage and availability: Available through NBN Gateway and will be on iRecord soon.

Quality assurance: Verification of all data by species experts (with automatic checks for date and location).

Training involved: Downloadable guidance is provided on our website, including species information and identification of their field signs. Surveying training is also available.

Partners involved: Biological Records Centre (NERC and JNCC), NBN, county mammal recorders, LRCs and TMP's

Number of participants: We have received nearly 3000 reports of sightings from the public.

Successes: We have forged new partnerships with many conservation organisations, with 14 county record centres and numerous NGO's currently working with us, and these continue to increase. This has already improved communication between conservation bodies and mammal researchers across Britain. As well as this, the project has attracted large numbers of volunteers. Our innovative open source online recording system allows the public to easily submit sightings of mammals and we have had more public involvement than ever before, with nearly 3000 online reports of sightings received in the first 7 months.

Lessons Learnt: Providing surveying resources to the public is of great importance, with training courses providing additional expertise to the downloadable guidance from our website. In addition to this, feedback is a good way of encouraging individuals to submit repeat reports of sightings. Regular preliminary analyses results distributed via our website and social media outlets are key in engaging public interest.

Increased cooperation between mammal conservation bodies is vital for accelerating development, with overall benefits for all.

Maintaining the verification process with reasonable timing can be a challenge when working with volunteer verifiers, but the situation appears to benefit from regular communication and assistance, as well as gentle reminders.

Policy links: There is currently so little mammal data available that it is very difficult to formulate any conservation policies that we suspect are very much needed for some species. In the production of the atlas we are hoping to increase awareness of the state of Britain's mammal records to increase reports of sightings through both the public and other conservation bodies. This will provide a baseline for future mammal conservation policy.

Wetland Bird Survey

Author: Andy Musgrove (Head of Monitoring - British Trust for Ornithology)

Primary aim of the project: to provide the principal data for the conservation of UK non-breeding waterbirds and their wetland habitats.

Type of project: Contributory

Brief introduction: Due to a number of factors, such as climate, habitat and wildlife protection legislation, the UK supports internationally important numbers of many species of waterbird outside the breeding season, many of which breed across a wide region of the Arctic. The UK recognises its international responsibility for these birds and WeBS is the monitoring scheme which aims to assess numbers and trends of these species, and the importance of individual sites for their conservation. The vast majority of the monthly counts are undertaken by volunteer birdwatchers. Moreover, local organisation of the counts is also largely volunteer-led.

Start date: In current form, July 1993, but follows on from equivalent schemes dating back to 1947.

Current status: Active and ongoing.

Geographic scope: UK, but equivalent schemes exist in Ireland (I-WeBS) and elsewhere in Europe and the rest of the world.

Routes to involvement: Many participants are drawn into the scheme through local networks and contacts, whilst others hear about it through organisational newsletters, websites, press releases etc. Data are now mostly submitted online (with a small number of paper submissions persisting).

Type of data collated: Monthly counts of waterbird species at defined locations.

Data storage and availability: Data are stored on the BTO's databases and are available on request (about one request per day is processed).

Quality assurance: Participants are recruited at local level, allowing a degree of ability assessment. Data are automatically checked for outliers at the time of submission, and then again during analytical stages.

Training involved: Some training courses are held, but most participants join the scheme already possessing the principal skill, i.e. identification of waterbirds.

Partners involved: Run by the British Trust for Ornithology, and additionally steered by the Royal Society for the Protection of Birds, Joint Nature Conservation Committee and Wildfowl & Wetlands Trust. WeBS is a partnership jointly funded by BTO, RSPB and JNCC (on behalf of CCW, NE, CNCC and SNH) in association with WWT, with field work conducted by BTO members and other volunteers.

Number of participants: about 2,000

Successes: Coverage of important sites for wintering waterbirds remains high, with almost all estuaries and larger inland wetlands counted every winter month (and many throughout the year). Efforts are also being made to understand the numbers and trends of more dispersed waterbirds on the large number of much smaller wetland sites. The volunteer workforce is very loyal, committed to the scheme, and locally active and engaged. The volunteers have also taken to a more efficient online system with enthusiasm. Results are reported on schedule each year, and external requests for access to data are dealt with promptly. Data feed into peer-reviewed research and environmental impact assessments, the latter ensuring that decisions concerning development around wetlands are made on the basis of unbiased data. A parallel set of lower frequency Low Tide Counts provides even more fine-grain information for assessing development proposals on estuarine sites. The most important wetlands in the UK have been given statutory designations (SSSI, SPA, Ramsar, etc) on the basis of the WeBS data, and the counts continue to be used to safeguard these sites. International cooperation works well, with effectively equivalent schemes in UK and Ireland and data exchange around cross-border areas and analyses at all-Ireland level; data are also submitted to the International Waterbird Census.

Lessons Learnt: Waterbirds are a popular wildlife group with amateur naturalists, leading in part to the success of WeBS. This group of species is relatively straightforward to identify, is fairly diverse (but not too species-rich), and has a good combination of predictability *vs* the unexpected; the observer soon gets a good feeling for what to expect, but surprises can turn up at any time. Moreover, the commitment and loyalty of the volunteer workforce is also be driven by "patch loyalty"; wetland sites tend to be well-defined, interesting and (mostly) attractive locations for the naturalists, and a feeling of "ownership" frequently develops. The scheme is methodologically simple (no transects or timed counts, just "count what's there"), and only requests that participants record waterbird counts, not detailed habitat or disturbance-related variables. The participants are given regular detailed feedback, both from the national organisers but also frequently from their local organisers (who themselves are volunteers). The technical systems sitting behind the scheme (database and website) are also widely appreciated by the volunteers, and make the job of managing the results much more efficient.

Policy relevance: WeBS data have been, and are, used widely for statutory site designation, reviewing consents and other ongoing management issues, and assessing the impacts of proposed industrial development, changes in recreational use, etc. In cases where development does go ahead, WeBS data are used to define mitigation or compensation measures; the parallel Low Tide Counts scheme is particularly important in this regard. Indices of individual species are combined to create the Wintering Waterbirds Indicator, published annually by Defra. Site-level WeBS "Alerts" are also produced every three years to draw attention to trends of wintering species on their most important individual sites. In conjunction with data from international partners, analyses of WeBS data also feed into measures of the effects (to date, and predicted) of climate change.

Project outputs: Main outputs each year are an annual report, containing summarised results, and a scheme newsletter, giving information about the scheme and interesting stories surrounding it. Both of these are mailed free to all participants, and can also be downloaded from http://www.bto.org/volunteer-surveys/webs/publications . In addition, WeBS data are widely used to produce scientific papers (http://www.bto.org/volunteer-surveys/webs/publications/webs-related-publications). They are also used extensively for applied purposes, such as environmental impact assessments.

Wider Countryside Butterfly Survey

Author: Zöe Randall (Butterfly Conservation)

Primary aim of the project: aims to more effectively monitor the changing abundance of widespread butterfly species across the general countryside and to provide a dataset to help evaluate and refine environmental policies.

Type of project: Contributory

Brief introduction: Strong emphasis has been placed on making sure that the WCBS is both scientifically sound (by adopting a random sampling approach) and efficient (a scheme with fewer visits to account for the fact that butterfly diversity across much of the general countryside may be low). The method is based on the BTO's Breeding Bird Survey (the 'BBS'), counting along two parallel 1-km long transects subdivided into 10 sections, located within randomly selected 1-km squares. The differences being that butterflies are counted in a more restricted area than for birds and at different times of the day. Only 2-4 visits are required compared to 26 on conventional butterfly transects.

Start date: June 2009

Current status: Active and ongoing

Geographic scope: UK

Routes to involvement: Websites, workshops, publicity including social media, local Butterfly Conservation Branch Champions (who recruit local recorders), National Coordinators (Butterfly Conservation (BC) & the British Trust for Ornithology (BTO)).

Type of data collated: Route maps, butterfly counts, dragonfly and day-flying moth counts, weather and recorder details**.** Other insects are counted in some years.

Data storage and availability: Stored on server at the Centre for Ecology and Hydrology (CEH) at Wallingford, local copy with BC Head Office. Local data disseminated to local co-ordinators. Dragonfly data is repatriated to the British Dragonfly Society and moth records are repatriated to the relevant County Moth Recorder, incorporated into local datasets which are then forwarded to the National Moth Recording Scheme (NMRS). The data are available through the NBN Gateway and from CEH/BC/BTO.

Quality assurance: Data are validated centrally at Butterfly Conservation and again locally by the local butterfly recorders and County Moth Recorders. Online data entry helps reduce errors.

Training involved: WCBS workshops have been held in key areas to boost participation. Survey guidance notes are available to download on the website.

Partners involved: The WCBS is part of the UK Butterfly Monitoring Scheme (UK BMS). It is jointly delivered by CEH, BTO and BC and is funded by a multi-agency consortium including CCW, Defra, JNCC, FC, NE, NERC and SNH. The UKBMS is indebted to all volunteers who contribute data to the scheme.

Number of participants: c.1200

Successes: The WCBS represents the first UK-wide survey of butterfly abundance using a random sampling framework and is important both in assessing the changing status of widespread butterfly species and in providing an indicator of the health of the wider countryside. An important dataset has been compiled on the distribution and abundance of butterflies and other insects across a representative sample of the UK countryside. The WCBS is successful as it requires less of a time commitment compared to traditional transects, and has a lot of potential to help assess and refine policy.

Since the launch of the WCBS in 2009 1,335 random 1km squares have been surveyed. In total 268,794 butterflies of 51 species including the 24 wider countryside species, have been counted. Unbiased annual abundance indices have been generated for all of the target wider countryside species. 121613 records; 5794 visits.

Using the BTO's Breeding Bird Survey (BBS) squares insect and bird trends from the same sites can be compared.

Media interest in this year's WCBS press release was high in 2012, 47 articles were published either online or in national and local newspapers from après release in May, reaching a staggering 17,987,508 people. Informing the public about the state of the UK's butterflies helps to put issues such as climate change and biodiversity loss into context.

Lessons Learnt: In under-represented areas, training courses have proved valuable in recruiting new recorders and improving uptake. Promotion of the WCBS via articles in external newsletters has also helped to boost coverage. Feedback to recorders is vital to maintain interest and enthusiasm, as is having active local co-ordinators. A few areas lack a local coordinator and coordination is undertaken centrally, this is not ideal and will be remedied in due course.

In some areas random squares are not within easy reach of volunteers coming forward, participation can be improved by stratifying squares by vice-county to create a more even distribution of squares across Butterfly Conservation Branches.

Informing the public about the state of the UK's butterflies helps to put issues such as climate change and biodiversity loss into context.

Policy relevance: Butterflies are important indicators of environmental change, the data collected from the WCBS can be used to assess the effectiveness of agri-environment and other land management schemes and to influence land-use policy. The data will likely contribute to UK and Country-level Biodiversity Indicators from 2013 inwards.

Project outputs: peer-reviewed papers, newsletters, articles for 'grey literature', data for research.

Wildflowers Count Survey

Author: Sue Southway (Wildflowers Count Survey Officer - PlantLife)

Primary aim of the project: An annual survey of common plant species with the aim of detecting underlying population trends.

Type of project: Contributory

Brief introduction: Wildflowers Count took over from Plantlife's Common Plant survey which started in 2000 but needed a revamp. The survey unit is a 1km grid square and surveyors are asked to devise a 1km walk through this noting presence and absence within 2m to one side of the path. Two plots can also be surveyed. There is a core list of 99 common plants chosen for ease of identification and their habitat preferences, but for those with good ID skills there is the opportunity to become a super-surveyor and note down other plants within the survey area that are not on the list.

Start date: March 2010

Current status: Ongoing

Geographic scope: UK, but there are some surveyors in Northern Island.

Routes to involvement: Website, workshops, publicity – eg County Life magazines, Rangers magazine.

Type of data collated: Presence and absence along a 1km walk, and a broad measure of abundance in two plots 5x5m and 1x20m. Habitat data is also asked for as a simple percentage of the area surveyed.

Data storage and availability: Data stored on site, not currently available through NBN. Some survey sheets are sent back by post, about half are entered online through Indicia.

Quality assurance: Currently none, but obvious anomalies are checked at the time of data entry and checking. As the core list is relatively small there is an element of trust that those electing to take part would not do so if they felt the ID to be beyond them. Many will send photo's for verification and this is encouraged.

Training involved: Workshops are a available but most people just use the guidance notes provided and email or telephone if they have a specific question. The survey is designed so that those with little botanical knowledge but a lot of interest and enthusiasm can participate. A core list of 99 species is supported by a full colour ID guide – arranged by flower colour not family. There is a Facebook page for those who want to share experiences, and knowledge and where photo's can be uploaded if ID help is needed, or photo's can be sent to Plantlife.

Partners involved: None

Number of participants: 2010 – 715 completed the survey, 2011 800 completed the survey. Overall about 2000 people have been contacted each year, and in 2012 900 packs have been sent to new registrants up to the end of June with more registering daily.

Successes: The uptake has been excellent and is growing, in 2012 so far we have sent out almost 100 survey packs to new registrations, and we are getting very good feedback from existing participants many of whom have asked to adopt a second square. The distribution of squares tallies well with the distribution of the population throughout the UK – squares are randomly allocated to be within 5km of the participants postcode.

Lessons Learnt: The lessons were learnt from the original Common Plants survey, and the main one was that the tasks required must be interesting for the participants, this gave rise to the Wildflowers Path which has proved immensely popular with about 75% taking up this option.

There is a need to be flexible so it is stressed that if an allocated square is unsuitable in any way then another can be allocated. If a potential surveyor has no access to transport then a square can be allocated locally, provided one is available.

The online database is to be improved as aspects of the design caused frustration, eg. If a square was surveyed twice all the information about it had to be re-entered not just the species information, so a log-in system has been ordered.

In the Common Plant survey the requirement was to survey 3 times between April and September, this was reduced to once in the Wildflowers Count, but analysis of the data from the former has shown that twice is the optimum number of visits needed a fact that has been disseminated via the newsletter.

The newsletter was also a lesson learnt, the need to keep people informed of what is happening with the survey and also to write brief but interesting articles on aspects of botany – they are well received.

Policy relevance: In the long term the data will be used to demonstrate plant population trends with a view to influencing government policy. In the shorter term it is an excellent way to engage people's interest in wildflowers and their habitats and get them outside looking at their neighbourhoods.

Project outputs: Quarterly newsletters sent via email, and available on the website. As this is a long term dataset no trend analysis will be done for some time.

Weather Observations Website

Author: Aidan Green

Primary aim of the project: To introduce a cloud based computing platform for collecting and sharing citizen weather observations as an operational service.

Type of project: The WOW project (http://wow.metoffice.gov.uk/) has largely been a contributory project (i.e. it is a website that has been produced and operated by the Met Office enabling people to submit their weather observations for the use of others). However the project has been run in a co-creative approach - for example, it engaged with key target user groups (in particular schools and weather enthusiasts) from the outset, including holding early workshops to inform the website design. The Royal Meteorological Society and the Department for Education were also engaged and supportive of the project from an early stage. WOW also has great potential to become more collaborative. The Met Office is very open to collaboration with other organisations who might be interested in building on the established WOW infrastructure and existing user community.

Brief introduction: The Weather Observations Website (WOW) was launched on 1st June 2011, and offers an exciting new online way for weather enthusiasts to submit and share their own manual and automatic weather observations and photographs.

In the first 12 months since launch more than 38 million observations were submitted via WOW; over 2000 separate observation sites created, and over 165,000 different visitors to the site from 152 different countries.

This new source of observations is a valuable extra source of meteorological information to forecasters, particularly in severe weather events and their onset, and research is planned for using the data to improve weather forecasting models.

WOW has potential to be used for other crowd source applications, exploitation by other government departments and agencies, or other applications in other sectors.

Start date: 1st June 2011

Current status: Active and ongoing operational service.

Geographic scope: Global, with a UK focus.

Routes to involvement: Website, direct engagement with schools and teachers, engagement with organised groups of weather enthusiasts.

Type of data collated: Currently WOW is a mechanism for collecting traditional weather observations (temperature, rainfall, wind, snow, etc), however users can also submit weather photos and free text weather diary information. In the near future the website will be updated to also enable users to report the impacts of weather (e.g. flooded roads, or damage to trees or property caused by strong winds, etc).

Data storage and availability:

The data is all stored by WOW on the Google cloud platform. All users can download their own data. Users can also control whether they are happy for other users to download their data – most choose to allow this option.

Quality assurance: Users submit "metadata" information about their weather stations. This information is then used to generate a star-rating (1-5) for each weather station. There are also various quality control rules for identifying gross errors. It is also possible for registered users to flag data that they suspect as erroneous. Finally, specialist software is used to scan photos and text for inappropriate content – thankfully, despite concerns at the outset of the project, this has not been an issue at all for the website.

Training involved: The website has been designed to be easy to use, and contains a lot of online support information.

Partners involved: The website has been produced and hosted by the Met Office. The Royal Meteorological Society and the Department for Education were also engaged and supportive of the project.

Number of participants: In the first 12 months there were over 165,000 different visitors to the site from 152 different countries.

Successes: WOW has been the Met Office's first large foray into the use of cloud based computing as a platform for collecting and sharing citizen weather observations. The data from WOW has proved to be a very useful additional source of weather information for weather forecasters, particularly in severe weather events such heavy snow. WOW offers a higher spatial and temporal resolution density of observations than could be sustainable with a single professional network.

The statistics below from the first 12 months are evidence of the success of the site, and have exceeded all initial expectations:

- More than 38 million observations submitted via WOW;
- Over 2000 separate observation sites created;
- Over 165,000 unique visitors to the website, from 152 different countries;
- Handled a spike of over 20,000 hits in one day, without interruption of service (since this spike, user numbers are generally up – suggesting maintained interest and take-up).

Feedback from users has been very positive, many comments along the following lines:

- *“Very impressive new site”*
- *“I am really enjoying the fact that my geeky recordings might be useful rather than just stored away.”*
- *“Thank-you for sharing data from my weather station on your site.”*
- *“Great to see some interaction with the home weather station community.”*
- *“Great idea and I have started contributing”*

The Met Office has also received many internal and external suggestions for further improvements and developments for the site, and there are plans in place for a significant phase of further development during the second half of 2012.

Lessons Learnt: Key lessons from the WOW project are as follows:

- Early engagement with the target user communities was very important for the success of the project.
- Resources were in place to ensure that any reports of problems following the launch of the site could be rapidly resolved.
- Due to extensive interest in WOW from other organisations there has been a near continuous demand for information and briefing papers about the project.
- A mobile-phone sympathetic webpage was difficult to design for WOW. Specific mobile phone Apps would be more appropriate, and this is included in future plans.

Policy relevance: The primary drivers for this new source of data include the requirement for an operational service providing high spatial resolution data for the verification of convective scale Numerical Weather Prediction (NWP) models, near real-time identification of localised severe weather events, and a mechanism for reporting and monitoring weather impacts.

Project outputs: The key output has been the successful introduction of WOW as an operational service providing access to a new source of high spatial resolution weather observations.

The Met Office is also currently co-supervising a PhD studentship investigating statistical methods enabling the automatic assessment of data quality, which may lead to the possibility of Numerical Weather Prediction assimilation of the dataset in the future.

Appendix 3: Structured interviews with citizen science data users

The answers have been made anonymous across the 18 interviewees. The numbering of the interviewees is consistent across all questions.

Q1. What are your current, priority needs for environmental observation data?

1. To be aware of what's changing, why it's changing, how policies can influence change, how policies have resulted in changes. Understanding interaction between changes. Monitoring whether situations are improved or compounded by interventions.

2. Need to monitor the environment in order to understand it and respond to change/problems.

3. Primarily background and supporting information for wider reporting.

4. Need to monitor the environment in order to understand it and respond to change/problems.

5. Observation data are key to demonstrating that environmental change is occurring. Only way to get necessary spatial and temporal measurements to understand how regional and national biodiversity and wider environments are changing is through citizen science.

6. To deliver policy objectives.

7. Observe environment and assess whether objectives of bidiversity policy strategy are being met. Help shape strategy design (what is changing and why so can plan policy response). Report on some specific policy reqs - WFD, EU Directives. Monitoring and analysis above and beyond this. Determine conservation problems.

8. Structured monitoring and general collection of biological records.

9. Data provider rather than user.

10. Background perspective for wider reporting particularly technology.

11. Primarily interested in long-term monitoring sets to look at climate change effects, but employ a range of temporal sampling scales. Use approach of inventory plots (long-term plots across UK) and integrated monitoring sites where study climate effects.

12. Wide range of biodiversity data relating to trends in species. Data on badged species particularly important. Wider range of habitat-based information (less of this than needed and it not always well structured). Broader environmental measures could include access to countryside, footpath conditions, landscape issues etc. To meet national and EU legislative demands.

13. IGNORE - NOT RELEVANT TO THIS ELEMENT.

14. Quality data on species distributions and habitats to enable implementation and reporting on Directives. Status of various land uses and how biodiversity on these sites is faring/changing for

monitoring agri-environment schemes and SSSIs. Also need contextual data to interpret the above, e.g. weather, soils, water.

15. Need species and habitat distributions, pressures and threats to meet reporting obligations under EU directives. Require biodiversity but also social aspects, waste etc - need data on key indicators (linked to UK Biodiversity indicators) meet reporting requirements. Agri-environment monitoring.

16. Increase public understanding of environmental issues and policies.

17. Change data on species distributions on a national scale. Also a general increase in data to help feed into or advise other policy programmes e.g. water Framework Directive, GBNNSIP.

18. To support their operational services. For this they need a global dataset of sustained quality. Long term data also helps to support climate change research.

Q2. Do you see a role for citizen science in supporting your (environmental observation) work?

1 – 18 unanimous agreement.

Q3. How would you envisage using citizen science?

1. a. As a tool to raise awareness amongst wider population, particularly of issues that are hard to communicate. Education value could be more valuable than the data value. b. To provide a broad spatial coverage of data.

2. a. To engage and raise awareness. b. To risk assess and direct more targeted work by their scientists. c. Not considered cost effective, or high enough quality to use directly for monitoring purposes.

3. Critical way into raising awareness and building a constituency. Problem is that evidence and monitoring base require systematic recording, which is not a strong point to many citizen science projects/schemes. There is mileage in tackling issue of non-systematic recording - standardising methods in a way that is both rewarding and useful? Modelling data is also difficult. Can we work backwards - what's needed from a science and policy viewpoint, then how do we design citizen science project?

4. 1. To support the information that we collect - not to replace or off-set effort in this area, but to add additional information to the work they do (to add richness to their dataset). E.g. bathing water monitoring, rainfall data. To help target resources/scientist activity E.g. Riverfly partnership 2. for pure engagement and awareness raising purposes.

5. Critical potential to provide the spatial and temporal data that we need. Involving people in monitoring is also a way to progress more active involvement in policy. Personal exposure data e.g. NOX - citizen science only way to get in most cases. Biodiversity data - only way to get coverage. Value at community level is in raising awareness of what 'my' environment is actually like.

6. 1. To help develop policy and (ensure agencies) deliver policy goals.

7. To provide scale, value for money, statistical advantages of a high sample size. [Expertise is implicit]

8. Monitoring and ad hoc reporting.

9. Ground-truthing by citizens could be very powerful e.g. to confirm forest cover, track storm events and channel movements (e.g. via fishermen's observations). At a global level, citizens can play a huge role in confirming presence/absence of forest cover, tracking deforestation etc.

Also for experimentation - can ask volunteers to manipulate land surface (e.g. place foil on ground) to test and validate interpretation of new equipment

11. 1. recreational feedback (ad hoc), local volunteer recorders with a site focus 2. New ways to supplement work in addition to above. e.g. to feed into a national inventory - assign permanent plots to citizen scientists? 3. Also for ground-truthing remote sensed data.

Don't forget the educational role and social benefits that involvement in citizen science provides.

12. Primarily to track species trends. Atlas data are useful, but trends are potentially more valuable. Also to track new arrivals.

14. To gather species records for baseline data allowing identification of priority areas, for case work e.g. development control, indicators and monitoring. Citizen science is essential as this cannot be done within existing resource limits. Most data would come to them via NBN Gateway.

15. As a key element of species data collection for monitoring and reporting purposes.

16. To engage the public with environmental issues. To reach socially deprived or geographically isolated communities.

17. The identification of new arrivals already works quite well. Would like citizen science to gather trend data, but also would like to encourage repeat monitoring at the same location to get time series data.

18. Citizen science data is needed to fill the geographic gaps - need better spatial and temporal resolution.

Q4. What would your aims be? What would you use the data for?

1. To inform construction of wider evidence base. Unlikely that citizen science could answer big questions alone, but could inform subsequent research activity.

2. To highlight areas for their scientists to investigate.

4. To support/sit alongside statutory body gathered datasets. Extra eyes and ears to spot risks that can then be responded to. The value is in this network of observers and the richness of the data they compile.

6. Very important as an engagement tool and for species-level data, it's the only information that we have. Critical in this respect - it's how we know what's where and how its changing. Role could be increased if we knew more about data quality and variation of quality.

9. Ground-truthing satellite data and refining interpretation of such data. There's opportunity to be very creative - is it raining? Go outside and check.

11. See Q1-3.

12. See Q3.

14. See Q1.

15. Reporting on the policy requirements mentioned above.

17. Research, and for advising on above policies (and others).

Q5. Do you currently run or fund citizen science? If no, do you think your organisation might in future?

5. Use rather than fund.

7. Fund others who deliver citizen science.

8. Yes, it's our core role.

9. Not directly, but support citizen science computer-based competitions.

11. Yes.

12. Don't run directly, but fund a significant amount of volunteer recording.

14. Mainly through contribution to NBN. Sometimes commission specialist surveys.

15. Contribute to NSS, sometimes financially, sometimes through other support routes, Memoranda of Association etc.

16. Yes, through a competitive science engagement grants programme. Also has non-competitive funding for schools.

17. Runs an engagement and citizen science project (HLF funded).

18. Have worked with voluntary observers for many years (going back hundreds of years).

Q6. How would you expect to see projects created?

1. Both contributory and co-created are essential in different circumstances.

4. Both contributory and co-created are essential in different circumstances.

5. Place for different approaches.

6. Depends on driver. To meet specific policy objectives, then contributory is necessary. If emphasis is on engagement then co-created is a fruitful approach - here's a problem, this is how it affects us, let's work together. Not something we do that effectively yet.

8. Rigid design so that is repeatable, top-down in a scientific sense, but volunteers and organisers feed into design and running of surveys.

9. Role for both. Contributory for ground-truthing.

11. Organisation would develop and then ask for feedback via user testing.

12. There is a role for all models, but potential discontinuity between community led projects and needs of end user. E.g. recording groups often record all they can find, but we're most interested in the badged species - species of particular policy concern.

15. Sometimes contributory, some more collaboratively.

17. Contributory is easier. Community are often more interested in 'what can be done' (outcomes of recording e.g.. A non-native species) which doesn't always fit with what policy makers require. Needs funding to get a scheme together that makes collaborative work easier. Project aims often have to follow what the funder wants - Lottery/charity funded projects often have a greater focus on engagement and participation than on science data and policy.

18. Some contributory, some are more collaboratively.

Q7. What would your geographic scope be? When running the project, how much freedom could you give participants in selecting their own sites, or for your needs would they need to be pre-selected?

1. Depends - broad scope projects will be at national level, grass-roots community projects will be at local level. Site choice will vary with project.

2. National. Site selection will vary.

4. National. Site selection will vary.

6. National. Site selection will vary.

7. National. Stratified random design encouraged - gives statistically representative trend information that is required. Needs sample allocation to get the randomness, but means that individual results are not neccessary significant at local scale. But long transect surveys do tell about the local place. If a protocol is locally meaningful it can be applied where you like. Completely self-selected citizen science of limited use unless sample number high enough.

8. Mostly UK wide. Randomly selected squares, participants told where to survey for most projects. General recording for others.

9. National to global. Unstructured surveys are quite feasible, especially if establish a crowd-sourced movement. Scientists can then follow-up interesting data. [Inference is that some applications will need to use pre-selected sites]

11. Currently GB-wide, but subject to change. National patterns of change, but also interested in local monitoring of individual sites. Pre-selected sites for deep studies.

12. National remit, but also need local site data (e.g. to monitor SSSi and NNR health). Citizen science has a big role in the latter.

14. National. UK perspective is often more pragmatic as NSS work on a UK scale. Would like targetted recording in sites that are protected or under management (c7% of England). Would like to see a more structured approach to surveillance akin to the BTO BBS which coordinates volunteer effort.

15. National.

16. National but particularly want to reach socially deprived (top 15% on IMD) or geographically isolated.

17. National and European. Are aware that citizen science in marine is primarily in the south west of England with a few hotspots elsewhere.

18. UK focus as a finer scale is needed here, but overall there's a global need.

Q8. What routes to involvement would you anticipate providing? (e.g. website, app)

1. Utilising strategic framework.

3. Motivations to record are highly variable and personal, often reject being steered in any way. Can be a mismatch between what volunteers want to do and what data users want to get out of it. Don't try to professionalise the voluntary sector. Perceived low expectation of the voluntary sector by some professional organisations can be a barrier. Remember that cannot devolve species recording from the trend in habitat concern - species add the colour. The new policy framework still needs the same species level effort.

4. Exploring how to develop a web-based mapping tool for observations.

5. Apps and sensors have great potential. Portable sensors are fascinating opportunity with great potential. Apps and phone technologies are growing area.

6. Website and apps are both critical tools.

7. Through other organisations.

8. Historically paper-based, now online and app.

9. Apps are very important, particularly as they use the GPS signal from phones to locate data precisely.

11. Websites, apps, on-ground face to face element.

12. Website where appropriate. Role of apps will continue to increase, but recorders will still submit in a range of formats. Bayesian keys on phones, combined with photo and GPS capability and automatic upload onto maps is very powerful tool. At the extreme end, passive recording is possible - sensors on bikes to monitor environment.

14. Would probably not provide this sort of thing themselves directly.

15. Would probably not provide this sort of thing themselves directly.

17. Website, printed ID guides.

18. Website with online recording and survey advice.

Q9. How would you seek to provide support?

1. They don't develop own projects, but support others in some cases. Have funded vol sector groups to run surveys e.g. assoc with agri-monitoring schemes. Aim to use a mixture of professional monitoring and voluntary input, dependent on project. Not their core remit to fund citizen science though.

2. Mixed approach, website critical (cameras/environment web). Don't develop citizen science projects themselves though. They use volunteer organisations as intermediaries (think fund some of them for specific projects?). But see Q 13.

3. You get from citizen science what you put into it. The more you support, the better the volume and quality of data. What about recording generalist species? Top-end recorders often less interested, yet these species are the ones that are favoured by habitat impacts. Public good at general id. But still need specialist recorders to spot the specialised species that tell us most about habitat quality.

4. Currently fund may projects to different extents.

6. They fund a lot of bodies that fund citizen science.

7. Fund others.

14. Would probably not provide this sort of thing themselves directly.

15. Fund some projects such as Butterfly Conservation and BCT to increase recording effort and encourage new people into recording.

16. See Q5 - would expect partners/grant holders to deliver.

17. See above.

18. Online advice on survey protocols.

Q10. Would you seek to specifically engage school children? Would you need to engage people who are already experienced? Would you seek to engage with anyone?

1. Broad - all sectors are important.

2. Broad - all sectors are important.

4. Landowners and natural resource users are primary targets. School children - not a priority.

5. Broad audience, engaging schools is profitable.

6. Audience = everyone, but need to be clear who we're engaging at each point.

8. General audience, but reality is that biased towards males and older males. Younger users more attracted to techno developments and multitaxa surveys. Don't specifically aim at school children, but do have open to anyone surveys and support Spring and AutumnWatch.

9. No specific target audience mentioned.

11. Very broad remit.

12. Broad audience, but specific targets of school groups and disadvantaged communities. Citizen science is just one way to reach these specific groups - not the only option. Dual aim of engagement and data gathering, depending on project.

14. Need good quality data but also recognise importance of public engagement and would see citizen science as an awareness raising tool, to gain political support for environmental issues. Recognise decline in expertise and have an ambition not just to restore previous levels but to develop even more in order for environmental monitoring to be sustainable.

15. To date, have mainly worked with NSS - are interested in wider public audiences but have not engaged much with this side of citizen science to date. Would like to think this will be developed in future. Some projects may meet education needs more than data needs.

16. Focus on adult environmental education - already so much out there for children. Educating parents also leads to children getting more involved.

17. Interested in both ends of spectrum. Recognise that best data comes from specialists but engagement is very important. The ideal is a scheme where you can progress through it, so start with just engagement then pick up skills and move up.

18. Very wide target audience. Would like access to high quality data but also want to increase their reach.

Q11. For the sort of citizen science and engagement you might seek, how much effort do you think you would require from participants? Would it be necessary to repeatedly visit sites?

1. Depends - different methods and standards needed for different projects.

2. Depends on the project, but emphasis is on behavioural change and engagement, not the data.

4. Will vary dependent on project. Definite call for repeated visits in some cases.

5. Random access projects can give skewed data, but systematic data can be problematic to set up - needs greater organisation. Auto feed from apps and recording devices is way forward. But, random access can also be beneficial as standard monitoring processes often ignore urban areas, yet that's where people live so dominated random surveys.

6. There is a need for longitudinal studies - but need to ensure make it clear why.

8. Long term, standardised repeated surveys and snapshot surveys. 2x a year transects.

9. Will vary.

11. In general, structured repeated sampling is most useful - this yields best results for long term studies. Also a place for ad hoc sampling e.g. surveillance.

12. Depends on project - includes repeated site monitoring for specific taxa and taxonomic groups.

17. All records welcome, but repeat data would be very valuable.

18. Single observations are welcomed, but repeat observations for a fixed site are better.

Q12. Would you anticipate people require specific equipment?

1. Depends on project.

2. Probably not.

4. Sometimes. E.g. phosphate probes for farmers as way of raising awareness and demonstrate their impacts (not interested in the actual data).

6. Not necessarily - but phone apps have a key role.

7. Technology - unsure about role of sensors, but can help become more effective at what doing. Major impacts are in automation - allows reduced costs, so can continue to support voluntary schemes. Transition of expertise - unless demographics changes, older volunteers will continue to donate most recording effort. New cohort will come through with the techno know-how.

10. Online recording will help data flow to an extent, but for species data there will be a slow take up in some sectors - paper-based records will remain (technology is not only solution). Difficulty accessing OS maps, marine charts and taxon dictionaries can all hol back development/utility of handheld apps. Stress importance of integrated online recording.

11. Possibly, as we move towards technological solutions to problems - e.g. tablet/pc based systems for regular monitoring sites.

12. [Some - for biological recording purposes].

14. Use of systematic survey protocols and standard formats for biological records is encouraged, which may require some equipment. Not all volunteers will want to follow set methods, but some will. Re equipment, technology is especially important e.g. apps. If we want better quality data and to create a partnership with volunteers, we have to provide the equipment/technology to enable volunteers to collect data more efficiantly and accurately.

17. Not very much. Increasing use of digital cameras, and some surveys require transects.

18. Usually.

Q13. What sort of data would be useful to you?

1. Broad range of environmental data.

2. Potentially a broad range of environmental data.

4. Broad range of environmental data. Riverfly and bathing water quality keep being mentioned.

6. Biological observations especially monitoring data [they effectively need the data that all of the bodies they fund require].

7. Biological records primarily. Value of non-bio datasets acknowledged as way of working out what's happening to biodiversity (e.g. rainfall, weather). Local validation of satellite data mentioned.

8. Biological observations, primarily of birds.

9. To suit ground-testing needs e.g. location of a potentially wide range of physical features and vegetation features.

11. Answered above - tree health, flushing times etc.

14. Good quality species and habitat records.

15. Good quality species and habitat records.

16. Evaluation data on the quality of the engagement experience. Not directly interested in the biological data but grant holders may be.

17. Species records.

18. Ideally climatic data in real-time.

Q14. Would you consider quality assurance of your data? Would it be critical?

1. Equal weighting for biological and physical environmental parameters, and behavioural data. Environmental change is a product of behaviour, if the process of data capture by citizen science changes their behaviour = end goal. Understanding data quality is critical, but standards and error rate that is acceptable will vary with project objectives.

2. Sceptical about value of data. Trust Met Office rainfall observation network data and expert-led volunteer monitoring in most cases. But check all other volunteer gathered data - role of non-expert public surveys is education, not data gathering. Don't use public citizen science data in their main evidence base. Main use of data at present is to highlight issues for their scientists to study/monitor and then gather their data on. i.e. to target resources effectively.

3. Varies. Top end recording, expect great data, but recognise they may not be involved for the same reason as you. Citizen science is a very broad line. Where you sit on it affects expectations and data output. Worth thinking more about modelling data - thresholds for effectiveness of use? Data quality issues are there but resolvable. Design needs to be appropriate to those taking part. Citizen science works well at a local level (i.e. the finer end of policy implementation), yet government agenda often needs national level picture. BTO, BC as rare shining examples of projects that tick all boxes.

4. There are prescriptive regulatory requirements that must be adhered to, but keen this does not become a barrier. At top-level, understanding data quality is critical. But need to capitalise on enthusiasm to interact and for this reason keen to accept e.g. anecdotal data - whatever is available.

5. Quality is important, but what's needed varies. For biodiversity data, the gains in spatial and temporal information can far outweigh any accuracy issues/concerns. For policy use, don't necessarily need the full 'scientific accuracy' - 'about' [this many] can be as useful as 'exactly' [this many].

6. Yes, it's critical. We need to do more work on quality assurance to convince some scientists = a mind shift. Technology can help with the data quality elements, but convincing statisticians is a harder job (spatial variability, differential effort etc).

7. Sampling and statistics is an understandable concern, but can be modelled for - and ignored if model shows is not an issue. Some evidence (BBS) that volunteer turn-over is less than for professionals. How critical is quality assurance? There is doubt around level of uncertainty that policy data can cope with. Confidence limits and validation levels will vary with citizen science, but you need to be aware of this for statistical purposes whether data are volunteer of professional generated. It's part of the process. Data controls (via method) need to be in place regardless of survey origin.

8. Quality is massively important, but depends on the particular survey and sample size. Have rigorous data checking at regional level. Use built in verification systems within on-line recording - preset thresholds for what's reasonable. Assumed valid if below threshold, checked by county recorders if above.

9. Engagement potential outweighs any concerns over data quality. Multitude of data points can negate any drop in quality. i.e. data quality can be managed. It does though depend on the question you are asking.

11. Yes, critical. Need to have some level of quality assurance, but better to have observations than not. As long as we know the level of quality, can adjust for error - a single observation isn't critical, as interpretation will be based on whole dataset.

12. Quality assurance is important, and needs to be considered by both the recording and data collating communities. For monitoring purposes, data quality is vital. There is a key role for recording schemes and other taxonomic experts in delivering quality assurance. Statisticians (e.g. in academic organisations) can play a role in assessing statistical interpretation of unstructured data (cf. structured monitoring data) and this should be encouraged.

14. Acknowledge that data from NBN Gateway isn't perfect but metadata available. Knowing quality of the data is the most important thing. Indicia is good for that with its built in validation/verification features. Knows of a French butterfly survey where data quality issues were present but sheer volume of data swamped any errors. Giving participants feedback on their own data is important e.g. highlighting if they've reported a species where there are several that look the same.

15. Data quality is very important. Unsure how 'wider public' citizen science can contribute to policy given data quality issues - would welcome more information on what can be gained from citizen science.

16. Only personally interested in quality of the engagement experience. Grant holders may be collecting data and have their own data quality standards/verification procedures - it's up to them.

17. Quality is important, but accept a lot of records that are 'OK'. There is some science snobbery over data quality form volunteers - believes that sheer volume will cancel this out, and also

would argue for better recording protocols to reduce error/variables. Make sure they flag up any problems so data quality is known. Verify all data for species range, rarity and ease of ID.

18. Star system where participants rate the quality of their equipment, and the rest of the community can 'complain' about a given site if they feel there's a problem with data quality. Includes has gross error checking then download a sub-set of these data for use and do their own quality control procedures - mainly by comparing data to computer models.

Q15. Would you seek to make the data publicly available? Would there be access restrictions?

1. Aim is to make available, but restrictions may apply to sensitive data. Sensitive data will be degraded prior to public release.

2. Yes, all.

3. General expectation from volunteer recorders on publicly funded projects that data are made available. But, how to motivate am-experts to deliver data for policy - they wont if don't want to.

4. As far as possible.

5. 100 % freely available.

6. Yes - transparency agenda.

7. Policy is data made available at resolution collected at, but in reality is constrained by other partners in dataset generation.

8. As far as possible and through different routes. Concern is misinterpretation of data - a point may not always be applicable on its own.

9. Where possible, but would not be feasible in all cases (e.g. commercial projects).

11. Yes.

12. Yes, data held back in exceptional circumstances.

14. Yes, almost all data comes via NBN Gateway.

15. Strong push for data to be publicly available, but are some species where info available publicly is downgraded due to sensitivity.

17. Yes. Everything publicly collected is publicly available. Hold some data from other organisations that is masked to 10km2. No real issues for sensitive species.

18. Participants tick a box to agree to the use of their data (almost all agree). This is then available via website in form of graphs, maps, historical records etc.

Q16. What would be your primary motivation (or need) for the data?

1. Education and to help direct resources.

2. Engagement and risk assessment.

4. See Q3.

6. See Q3.

9. Primarily for validating observations.

11. Combination of data and engagement. Need to balance this approach, but involving more people is in line with policy.

14. See Q1.

17. Research.

18. Predictions.

Q17. Other comments

1. Would like to see examples of citizen science projects that look at less charismatic taxa and topics that are not inherently exciting - soils etc

2. Needs to be recognised that citizen science is not a cheap way to gather data - don't underestimate the effort (infrastructure, training, feedback, events, website etc)

5. We are at the beginning of a technological revolution - sensors and new ways of collecting information. Phones are way forward. Citizens need to put pressure on companies to produce the sensors that they need - making it easier to record in every sense - can we enhance new technologies to enable us to do this? Dialogue between technologists and software developers and users is critical. New technologies need to incorporate data cleaning.

7. Note to self - ensure seek balanced, thought out review based on all evidence gathered.

8. What works - feedback, thanks, bringing people on.

14. Would like our report to highlight that data and citizen science isn't free, but supporting volunteer recording is cheaper and more sustainable than paying professionals. Other reports and reviews on volunteer data and recording have taken place - would like to see some conclusive actions come from this one.

15. Value finding out more about what can be done with citizen science data - sharing good practice.

16. Works in the policy of science engagement, promoting things that connect the public with science.

17. Policy makers are keen but haven't got any money - if they did, we could soon come up with a working system for better data collection and sharing.

18. An aspect of their work similar to citizen science is their work with industry - gathering data from GPS satellites and commercial aircraft. Commercial aircraft in particular provide data from otherwise unreachable places

Q18. Risks

1. Abuse of volunteer resource, especially now that financial conditions are difficult. Engaging mass audiences is desirable, but risk of data variability - although this can be managed. Austerity and Big Society could impact adversely on citizen science. Public fatigue and confusion - there are lots of projects out there.

8. Concerned about proliferation of projects and we need to be careful about the messages that are given out.

10. Loss of taxonomic expertise as a threat - training new generation of recorders is a priority, but takes time (your own time). How much time do people have to learn to id? For some groups it is not easy and can take a lifetime of experience to become truly expert - not a quick fix.

15. Expect wariness from some quarters especially where there is less experience of using volunteer data.

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