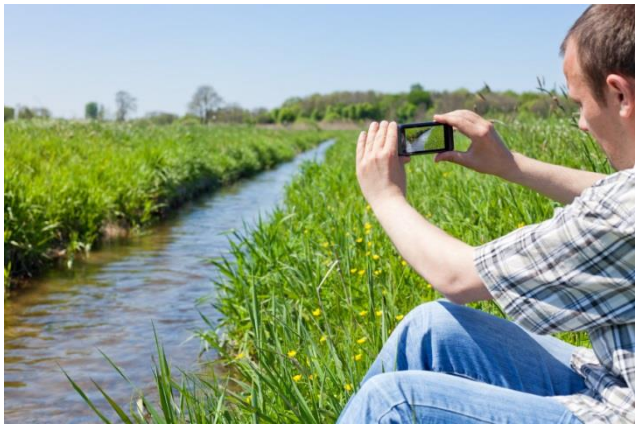
HOUSES OF PARLIAMENT
PARLIAMENTARY OFFICE OF SCIENCE & TECHNOLOGY

POSTNOTE

Number 476 August 2014

Environmental Citizen Science



Environmental citizen science traditionally involves members of the public submitting sightings of wildlife to NGOs or records centres, but emerging technologies have recently broadened its use to all kinds of environmental data. This POSTnote summarises different types of citizen science projects, policy-relevant applications and the benefits and challenges of volunteer collected data.

Overview

- Environmental citizen science encompasses a broad range of projects in which volunteers partner with scientists to answer real-world questions at geographic scales too large for a scientist to study alone.[1]
- Advances in technology have increased the diversity of citizen science projects. They now include the use of sensors to gather data about air and noise pollution.
- Data collected by volunteers already plays a critical role in environmental monitoring.
- With appropriate quality assurance measures, citizen science can generate high quality environmental data.
- Citizen science is increasingly being used to inform policy and practice, and as a form of public engagement with science and nature, empowering communities to engage local authorities about environmental issues.

Background

Although 'citizen science' is a relatively new term, the involvement of volunteers in environmental monitoring is not a novel practice.[2,3] In the UK, volunteer naturalists have submitted records to recording schemes and societies for decades.[4,5] For example, the British Trust for Ornithology (BTO) has been running schemes like the Breeding Bird Survey since the 1930s. An estimated 100,000 amateur naturalists contributed to such projects in the UK in 2005.[6]

However, over the past decade, technological advances have led to a rapid increase in the range of ways in which volunteers can assist with data collection and analysis (Box 1).[7,8,9] Studies have suggested this may have increased the number of citizen science research projects, but the total number of volunteers taking part has not yet been estimated.[5,10] There are also concerns about managing such large datasets, and perceptions that data are of low quality (POSTnote 468). Government departments and agencies now regard citizen science as a way to involve the public in the development of research, monitoring and evidence to inform policy. For example, Defra's Tree Health and Biosecurity Action Plan and National Pollinator Strategy both call for the training of volunteers to assist with monitoring.

Types of Citizen Science

Volunteer naturalists have a wealth of knowledge about wildlife and are often better at species identification than professional scientists.[11] They can supplement the work of professional scientists by gathering data on species distributions, weather patterns, pollution and plant disease outbreaks across a far wider geographic and temporal scale than would be financially or logistically feasible through other means.[12-19]

Box 1. Types of Citizen Science

There are different ways of categorising citizen science projects.[20,21] One such classification includes the following three types:

- **Contributory** – designed by scientists. Members of the public contribute data, for example via smartphone apps.[21]
- **Collaborative** – designed by scientists. In addition to data collection, volunteers refine project design or contribute to the analysis or dissemination of results.[21]
- **Co-created** – scientists and volunteers work together to design and conduct projects. Volunteers are involved with most or all stages.[21] An example is the Riverfly Partnership: a network of anglers and voluntary organisations that monitor the health of rivers and aquatic invertebrates.[22]

Box 2. Using Technology to Collect and Classify Data

Norfolk Bat Project
The British Trust for Ornithology (BTO) has enlisted over 700 volunteers to survey bats across Norfolk. Volunteers sign up online, collect a static bat-detector from one of 21 centres hosting equipment and put up it in their allotted 1km^2 grid square. Echo-location data are automatically collected by each detector as bats pass close by. After three days, volunteers return the detector and post the memory card containing bat recordings to the BTO. The data are analysed using an algorithm that can assign bat calls to species. Volunteers are sent the results of their survey within a few days to increase motivation. Over 400,000 bat records have been collected each year since 2013, compared to 1,000 per year before the project.[23]

Great Crested Newt Surveillance
The UK Freshwater Habitats Trust recently conducted a pilot project to test whether the presence of Great Crested Newts, a European Protected Species, could be detected from pond water samples collected by volunteers. The method detected Environmental DNA (eDNA) which is released into the environment via faeces, mucous, and shed skin. Great Crested Newts were correctly detected from water samples 99.3% of the time with no false positives. The method would allow volunteers to submit pond water samples from across the UK without the need for a protected species license.[24] It may give planning authorities a more accurate picture of Great Crested Newt distributions across the UK, reinforcing the need for some restrictions and reducing the need for others.

Zooniverse
Zooniverse is an online platform hosting a range of ecology projects that request the assistance of volunteers to help complete research tasks by classifying images or audio files. For example, in the *Snapshot Serengeti* project, volunteers scan through camera trap images collected from the Serengeti National Park and classify the numbers, behaviours (for example, moving, eating or interacting) and species present in each image from a list of options.[25]

Citizen science also has the potential to streamline environmental data collection and validation, and engage with new audiences.[19] The uses of new technologies are outlined below.

Data Collection

Organisations are generating unprecedented volumes of environmental data. For example, more than 38 million observations were submitted on the Met Office's Weather Observations Website in its first year (for more examples, see Box 2).[47]

Some organisations are using more automated ways of collecting environmental data. Sensors allow volunteers to collect automated data on variables such as weather, air quality or noise pollution in areas not covered by official surveys.[15,16] At a local scale, communities are using sensors to monitor air quality and noise pollution to inform discussions with local authories.[7,16] Although in some cases sensors may improve data quality, some low cost devices are designed for public engagement rather than scientific research so accuracy may not always be paramount.[7] An increase in the use of automatic sensors may reduce public engagement by removing the need to interact with the environment.[7] The use of smartphones to submit data is also becoming increasingly common.[5,13,26,27] According to Ofcom, 51% of the UK population now own a smartphone

Box 3. Smartphone Apps for Citizen Science
Smartphone apps are used in biodiversity monitoring projects. Volunteers can also use them to submit sightings of invasive non-native species (e.g. Plant tracker app[13]), litter (EU Marine Litterwatch app[28]) and tree disease sightings (TreeAlert app[29]).
Advantages include:[5]
- instant data entry where records are collected
- simultaneous recording of GPS location when records are entered
- easy uploading of photos to verify sightings
- an easy way to convert observers into recorders

However, there are a number of limitations including:
- the alienation of people without smartphones
- the high turnover of new apps
- high development costs

making them a good tool for citizen science.[30] Their advantages and disadvantages are summarised in Box 3. Data are also being harvested from social media feeds such as Twitter (POSTnote 460) to improve the reporting of earthquakes and natural hazards.[31,]

Data collected by volunteers can augment those collected through official channels. The Met Office launched the Weather Observations Website (WOW) in 2011 and has received over 250 million weather observations in the first three years providing a valuable extra source of weather information, particularly during extreme localised events.[32]

Data Classification

Online crowdsourcing platforms such as Zooniverse[25] (Box 2) and iSpot[33] enlist volunteers to classify or interpret vast collections of data (typically images, audio files and historical records) from their personal computer.[7] Other repetitive scientific tasks have been adapted into online games (gamification),[34] as the human eye can recognise patterns computers miss. For example, *Fraxinus* challenges users to search for a given arrangement of coloured leaves (representing parts of a gene) on the screen to help identify genetic sequences which show resistance to Ash dieback.[34] Cyber-science projects like these provide fun and enjoyable ways to engage new audiences with science.

Using Citizen Science to Inform Policy

Citizen science is increasingly being used in a policy context. For example, in a forthcoming EU White Paper, citizen science is identified as an important tool for meeting the aims of the Europe 2020 strategy for research excellence and is also relevant to many topics of the Horizon 2020 research funding programme.[8] Other policy-relevant applications are summarised below.

Designation of Protected Areas

The *Seasearch* citizen science programme – co-ordinated by the Marine Conservation Society – enlists the help of volunteer scuba divers to map the species and habitats found in the near shore zone around the whole of Britain and Ireland.[35] Data from the programme were submitted as part of the Defra's consultation on Marine Conservation Zones in the UK.[36] The data collected as part of BTO's

Wetland Bird Survey are used in the designation of Special Protection Areas under the European Wild Birds Directive.[37]

Environmental Impact Assessments

Ecological consultancies and local authorities rely on biodiversity data collated by Local Records Centres and the National Biodiversity Network (NBN) Gateway as part of the planning process.[38] These data are often used in Ecological Impact Assessments (POSTnote 429) to determine how species and habitats may be affected by proposed developments.

Environmental Indicators

Seven out of the 26 UK biodiversity indicators rely on volunteer-collected data and it has been estimated that volunteers are capable of monitoring 63% of the 186 indicators that the UK is obliged to monitor through twelve international biodiversity agreements.[11,39,40] Data on bird distributions collected through the BTO's volunteer schemes and similar schemes across Europe have been used in EU Birds Directive reporting. [41-43] Similarly, data collected by volunteers on birds, butterflies, bats and vegetation are used in EU Habitats Directive reporting.[42] The Breeding Bird Survey is one of the data sources used to evaluate the effectiveness of agri-environment schemes in the UK.[44] Citizen science plays a role in measuring progress towards the targets in the EU 2020 Biodiversity Strategy and the Aichi Targets of the Strategic Plan for Biodiversity for the period 2011-2020 for the Convention on Biological Diversity.[7]

Identification of Invasive species or Disease Outbreaks

Volunteers are already contributing to Defra's Tree Health and Biosecurity Action Plan by reporting symptoms of tree diseases.[18] Reporting of invasive non-native species has also enabled researchers to map their distributions across the UK.[45] These data will enable the UK to meet its obligations to monitor, report and respond to the introduction of non-native species as part of the EU Invasive Species Legislation.[46]

Advantages of Citizen Science

Where it is appropriate for the task at hand and is carried out with the necessary scientific rigour, citizen science can have a number of advantages, as outlined below.[11,47]

Public Engagement with Science and Policy

The EU Biodiversity Strategy describes citizen science as a valuable means of gathering high quality data while engaging citizens with biodiversity conservation.[48] Evidence suggests that involvement with citizen science can positively affect participants' attitudes and behaviours towards the environment.[49] It has been shown to be an effective tool for community engagement in deprived areas.[50]

In some cases, citizen science can increase participants' science literacy, allowing more informed decisions about scientific and environmental issues, promoting sustainable lifestyles and enabling people to learn new skills, often with value for future employment. [10,51,52,64] This is a key objective of the EU Horizon 2020 strategy.[8]

Community Empowerment

Projects co-developed by scientists and communities, may equip residents with the tools and expertise to collect evidence about problematic environmental issues in their area, driving a participatory democracy and encouraging environmental activism.[53,54] For example, in collaboration with the social enterprise Mapping for Change, local residents collected data on noise levels near a scrapyard in the London district of Deptford.[55] Volunteers presented the local authority with evidence that the operation violated noise limits. After its own investigation, the Environment Agency revoked the scrapyard licence.[56]

Cost Effectiveness

Projects can often incur substantial costs to fund IT support, recruit and engage with volunteers, and design and analyse experiments.[4] However, for larger scale projects, citizen science has been shown to be cost effective. For example, in 2007, a £7 million government investment into volunteer monitoring schemes generated data estimated to contribute time in-kind worth £20 million.[57] The French National Museum for Natural History's Vigie-Nature citizen science biodiversity monitoring programme is estimated to save the French Government an estimated €1-4 million per year.[7,58]

Improved Productivity

The lag between data collection and analysis for environmental monitoring can be reduced through the widespread use of smart phone apps what facilitate immediate data entry (Box 3). The use of crowd sourcing can also speed up the classification of images for scientific research that would be unachievable by a small team or computer. Volunteers can also contribute to organisations' basic monitoring work freeing up professional scientists to direct their efforts to priority sites.[11] For example, where invasive species or diseases have been reported.

A recent study by Natural England indicated that efficiency might be increased further still if volunteers collect data on multiple species in a habitat simultaneously.[59] A feasibility study suggested that multi-species surveys encouraged collaboration between organisations and produced more standardised data.[59]

Challenges of Citizen Science

Quality Assurance

Studies have shown that volunteers and professional scientists can yield very similar results.[60] However, due to differing levels of expertise, motivation, time and equipment available, there is a perception that data collected by volunteers can contain greater levels of error (such as measurement error) or spatial bias (volunteers may be more likely to visit sites where rare species are known to be present). [7,12,61] The widespread use of citizen science is currently hindered by this perception.[10,61–63] Quality assurance measures can reduce the potential for error (Box 4).

Box 4. Quality Assurance Measures

Quality assurance methods are essential for reducing potential error in research projects.[7,64,65] A recent study reviewed 234 citizen science projects and found that most included some degree of quality assurance.[4] However, the measures put in place are not always explicitly cited in academic publications, which can lead to a lack of confidence in results.[51,66] Measures include:

- **Best practice guides** – Citizen science is not appropriate for all projects. The use of best practice guides is advocated by the UK Environmental Observation Framework (UKEOF) to determine whether it is appropriate for the proposed research and to ensure that it is carried out with the necessary rigour.[11,47]
- **Observer training** – Volunteers are often required to undertake training before they take part in the project.[7,35] For example, the 'ObservaTree' programme run by the Food and Environment Research Agency, the Woodland Trust and Forest Research has trained a network of volunteers in tree health monitoring to meet skills-shortages.[67] Others provide information packs and species identification guides in order to reduce inter-observer variation.
- **Validation** – A set of filters can be used at the data entry stage to avoid inputting errors and ensure that data are entered in the correct format.[72]
- **Verification** – Scientists or experienced volunteers judge the feasibility of the reported observation. This can resolve issues such as animals reported outside their known range, or occurring at an unexpected time of the year. Photographs are sometimes required to verify unusual sightings.[68,69]
- **Accounting for observer error** – It is often possible to quantify levels of observer error (by comparing volunteer results to expert results) and apply an error-correction factor to the dataset to account for it.[61] 8,000 volunteers across the UK scored the amount of damage which had been caused to their local horse-chestnut tree leaves by the horse-chestnut leaf mining moth (*Cameraria ohridella*). Researchers were able to account for variation in volunteer results using this technique.[69]

Data Bottlenecks

The analysis of large data sets can be challenging.[70] Moreover, many citizen science data collection methodologies require a small number of professional scientists or experienced volunteers to conduct the verification process.[59] The development of computer verification systems may prove effective in preventing bottlenecks.[71] The NBN has recently developed software (the NBN record cleaner) with which to automate the verification of some records using smart filters.[72] Research by Natural England suggests that 44% of species records entered onto NBN can now be verified automatically, reducing demands on experts.[59]

Maintaining Volunteer Engagement

There is the potential for volunteers to become fatigued, or overwhelmed by requests.[5] Understanding what motivates volunteers to take part may avoid tensions between personal objectives and project objectives.[11] Research suggests that volunteers may be motivated by social interactions, gaining new employment skills, contributing to social or environmental policy or by the opportunity to use their expertise. [7, 62, 64,73]

While the increasing use of digital technologies has the potential to reach new audiences, it could also isolate groups of people who lack the technological expertise or equipment necessary to take part, potentially leading to a digital divide. [4,74] Many programmes offer multiple input methods (for example, offering paper forms as well as online forms and mobile phone applications) but this could lead to inefficiencies. Much depends on the complexity of the survey and the underlying database structure.

Making the Best Use of Data

A number of factors can affect the ability of an organisation to either access or use environmental data. At present, not all volunteer datasets are open access: there are concerns about sharing location-specific data (such as locations of rare species); some contracts give funding organisations rights to the data; and sometimes data are held back because organisations or individuals want to be the first to publish the results.[7]

Those data that are accessible are often fragmented or have missing data making it difficult to combine them with other datasets.[5,75] While some organisations have processes in place to efficiently share data, other datasets remain isolated and only used for a specific purpose.[4] The use of 'cyber infrastructures' such as *Indicia* is being encouraged to allow the collation of multiple datasets and promote consistent data standards [5,12,76]

Environmental organisations will need to update their IT processes and will require staff to learn big data skills (as has been the case in the business sector, POSTnote 468 and POSTnote 469) if the data collected through citizen science are to be used effectively.

Endnotes

1 Cohn, 2008, *Bioscience,* 58, 192-197
2 Irwin,1995, *Citizen Science: A Study of People, Expertise and Sustainable Development*. Routledge, Oxon, UK.
3 Silverton, 2008, *Trends Ecol Evol*, 24, 467-470
4 Biological Records Centre: recording schemes and study groups
5 Roy *et al.,*2012, *Understanding Citizen Science and Envrionmental Monitoring*
6 Ellis, R., *et al*, 2005, Nature: Who Knows? Lancaster University Report
7 Science Communication Unit, University of the West of England, 2013, *Science for Environment Policy In-depth Report: Environmental Citizen Science*.
8 Socientize, 2013, *Green Paper on Citizen Science*
9 European Environment Agency, 2012, *The Value of Citizen Science*
10 Crall *et al.,* 2012, *Public Understanding of Science*, 22, 745-764
11 Pocock *et al*., 2014, *Choosing and Using Citizen Science: a guide to when and how to use citizen science to monitor biodiversity and the environment.* Centre for Ecology & Hydrology
12 British Trust for Ornithology Breeding Bird Survey
13 PlantTracker App
14 iRecord
15 Allot, 2010, Presentation: The British Rainfall Network in 2010
16 Mapping for Change
17 AshTag App
18 OPAL Tree Health Survey
19 Dickinson, 2010, *Annu Rev Ecol Syst*, 41, 149-172
20 Haklay, M., 2013, Citizen Science and Volunteered Geographic Information – overview and typology of participation in Sui, D.Z., Elwood, S. and M.F. Goodchild (eds.). *Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice.* Berlin: Springer. pp 105-122
21 Bonney *et al*., 2009, *Public participation in scientific research: defining the field and assessing its potential for informal science education.* A CAISE Inquiry Group Report. Center for Advancement of Informal Science Education (CAISE), Washington, D.C., USA.
22 The Riverfly Partnership
23 Newson et al., 2014, *British Wildlife,* 25, 264-269

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology. POST is grateful to Lucy Anderson for researching this briefing, to the BBSRC for funding her parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact the co-author, Jonathan Wentworth.

24 Biggs, J. *et al*., 2014, *Analytical and methodological development for improved surveillance of the Great Crested Newt, Defra Project WC1067*. Freshwater Habitats Trust, Oxford.
25 Zooniverse
26 Aqua Invaders App
27 Great British Bee Count
28 European Environment Agency: Marine Litterwatch
29 Forestry Commission: TreeAlert App
30 Ofcom: Tablets and Smartphones continue to see rapid growth in take-up
31 Young *et al.,* 2013, Transforming Earthquake Detection and Science Through Citizen Seismology. Washington, DC:Woodrow Wilson International Center for Scholars.
32 UK Met Office: Weather Observations Website
33 iSpot Nature
34 The Sainsburys Laboratory: Fraxinus
35 Seasearch
36 Seasearch Annual Report 2012
37 Stroud *et al*., 2001, *The UK SPA Network: its scope and content. JNCC*
38 Institute of Ecology & Environmental Management, 2006, *Guidelines for Environmental Impact Assessments in the United Kingdom*
39 Defra, 2012, *UK Biodiversity Indicators in Your Pocket*
40 Danielson *et al*., 2013, *Conserv Lett*, 1, 12-14.
41 European Bird Census Council: Pan European Common Bird Monitoring Schemes
42 JNCC, 2013, *Refreshing JNCC's surveillance and monitoring evidence role*
43 JNCC, 2013, *10th Report by the United Kingdom under Article 12 on the implementation of the Directive on the conservation of wild birds (2009/147/EC) from January 2008 to December 2012.*
44 Baker *et al*., 2012, *J Appl Ecol*, 49, 871-882.
45 Roy *et al*., 2014, *Biol Invasions.* doi10.1007/s10530-014-0687-0
46 European Commission, 2013, *Regulation of the European Parliament and of the Council on the prevention and management of the introduction and spread of alien species*
47 Tweddle, J. *et al*., 2012, *Guide to Citizen Science: developing, implementing and evaluating citizen science to study biodiversity and the environment*.
48 European Commission, 2011, *Our life insurance, our natural capital: an EU biodiversity strategy to 2020*
49 The Conservation Volunteers, 2014, *Volunteering impacts*
50 OPAL, 2013, *Community Environment Report*
51 Rowland, 2012, *Nature,* 17,10054
52 Conrad & Hilchey, 2011, *Environ Monit Assess*, 176, 273-291
53 Ala-Mutka, 2009, *Review of Learning in ICT-enabled Networks and Communities*
54 Mueller *et al*., 2012, *Democracy and Education,* 20, Article 2.
55 Mapping for Change: Pepys Air Quality
56 Gura, 2013, *Nature*, 496, 259-261.
57 Mackechnie et al., 2011, *J.Environ Monit,* 13, 2687.
58 Levrel *et al*., 2010, *Ecol Econ*, 69, 1580-1586
59 Natural England, 2014, *Draft report: The Defra Fund for Biodiversity Recording in the Voluntary Sector (2012-2014)*
60 Holt, B. *et al*., 2013, *Methods Ecol Evol*, 4, 383-392.
61 Bird *et al*., 2013, *Biol Cons*, 173, 144-154
62 Grove-White *et al*., 2007 *Amateurs as experts: harnessing new networks for biodiversity,* Lancaster University.
63 Riesch & Potter, 2013, Public Underst Sci, 23, 107-120
64 Gollan *et al*., 2012, *J Environ Manage,* 50, 969-978
65 Delaney *et al*., 2008, *Biol Invasions,* 10, 117-128
66 Gouveia *et al*., 2004, *J Environ Manage*, 71, 135-154
67 Fera, 2012, *Press release:Training the trainers – leading best practice on tree and plant health.*
68 Gardiner et al., 2012, *Front Ecol Environ*, 10, 471-476
69 Pocock & Evans, 2014, *PLOS ONE*, 9, e86226
70 Van Strien *et al*., 2013, *J Appl Ecol,* 50, 1450-1458
71 Kelling *et al*., 2011, eBird: *A Human/Computer Learning Network for Biodiversity Conservation and Research*
72 National Biodiversity Network: NBN Record Cleaner
73 Wiggins & Crowston, 2011, *44th Hawaii International Conference on System Sciences,* Hawaii.
74 Newman *et al*., 2012, *Front Ecol Environ,* 10, 298-304
75 Conrad, 2011, *Environ Monit Assess,* 176, 273-291
76 Indicia database