Methods

Citizen Science: a new tool for UV-B research?

Alan G. Jones, ORCID: 0000-0003-3047-3338
Earthwatch, Mayfield House, 256 Banbury Road, Oxford, OX2 7DE, UK

DOI: 10.19232/uv4pb.2015.1.11

Introduction

In recent years, 'citizen science' has emerged as an area of growing interest. Recognition of benefits for society and environmental research has enhanced interest in this approach to engaging the public and obtaining 'crowd-sourced' data. Science funding bodies, wishing to raise the profile of their activities or to justify publicly-funded science, also regard these benefits favourably. Powerful technology has democratised tools like smartphones for data collection, transmission and storage, to an extent that would have been unimaginable two decades ago. Citizen science has become an established part of the research landscape which is here to stay. A Google Scholar search for related terms ["citizen science"+ecology] reveals that publication rates in this area are rising exponentially, with the number of publications doubling in less than 4 years (Fig. 4.1). The benefits of citizen science for researchers and the public, combined with its growing acceptance as a method for acquiring data, means researchers able to use citizen science effectively will have clear advantages in enhancing the impact of their work.

Who is a citizen scientist?

From the large and conspicuous citizen science projects arising over the last decade, often supported by national publicity campaigns and involving thousands of people, it might appear these are the only citizen science approaches available. In reality, citizen science projects can operate at a range of scales and be directed at a diversity of questions. The history of volunteer-lead science demonstrates the instrumental role of 'citizen scientists' over the last few centuries, which has often taken place in low-key ways. Amateur botanists in Britain have collected plant phenology data since the 1730s, this is now used to support our understanding of climatic impacts to plant communities (Sparks and Carey 1995), and similarly bird migration data have been collected in Finland since the 1740s (Greenwood 2007). By way of example, these contributions demonstrate how citizen scientists can supply longitudinal data across potentially immense ranges of space, time and even taxa, and that such initiatives are open to anyone.

Until recently, only experienced groups of specialist volunteers were utilised for large biological recording efforts, but the public are now becoming part of this space, as the quality of data from citizen science has been repeatedly validated by studies on its accuracy (e.g. Butt et al. 2013; Crall et al. 2010, 2011). Growing confidence exists in citizen science data, such that greater numbers of people than ever before can now contribute to valid datasets of high scientific value. Potentially all layers of society, in particular, disadvantaged groups, children or senior citizens, can participate and gain useful environmental experience (Bonney et al. 2009).

Opportunities for citizen science within UV-B research

A Google Scholar search for the combined terms `"citizen science"+ecology+UV-B` demonstrates that UV-B ecologists have been slow to exploit this scientific momentum. Since 1994 there have been only 28 articles published using this combination of terms and no studies feature citizen science methods to collect ecosystem data on UV-B impacts. There are clear opportunities available for UV-B scientists to embrace new innovative citizen science methods to collect data. Developing research ideas suitable for citizen science projects will be the first step in this (e.g. Box 1). As a phenomenon, UV-B has close links to natural processes which interest many members of the public. The 'ozone hole' which was well publicised in media throughout the 1980s is likely to be a good lead in point for many UV-B research projects looking to connect with the public, particularly that cohort who grew up in the 1990's and may now have families themselves. UV-B also directly influences food quality, skin cancer risks, plant-insect communication and other more hidden aspects of photobiology, and it also involves numerous import-

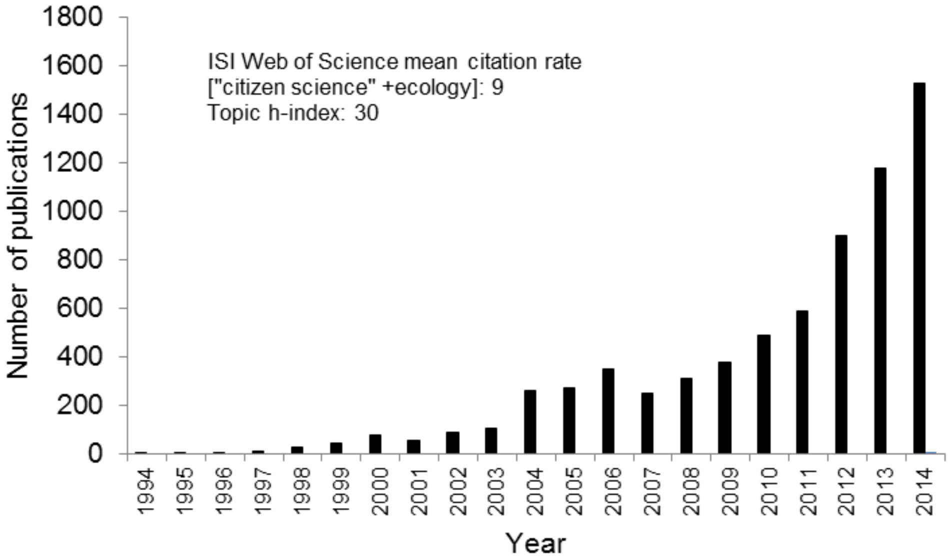

Figure 4.1: Number of publications per year with search string ["citizen science"+ecology] from a Google Scholar search.

ant interactions with global change. These topics each have strong links with the school curriculum (Gaberščik et al. 2015) and, therefore, may become engaging areas for citizen science projects to be developed that will be suitable for children, families and young adults.

Why be a citizen scientist?

The motivations of participants are the key to engagement in particular research topic. Numerous projects often featuring charismatic topics close to the hearts of the public were reviewed by(Roy et al. 2012) (e.g. garden birds (Big Garden Birdwatch (Protection of Birds 2015); horse chestnut trees (Conker Tree Science (Pocock and Evans 2015)); bats (National Bat Monitoring Programme nbmp.bats.org.uk); ladybirds (UK Ladybird Survey (Roy et al. 2015)); butterflies (United Kingdom Butterfly Monitoring Scheme (CEH 2015))). Although less charismatic topics, including earthworms and soil (OPAL soil and Earthworm Survey (OPAL 2015)), or soil properties (mySoil (Survey 2015)) also feature. Motivations for potential citizen scientists are not necessarily defined by a charismatic topic, but from an opportunity to contribute meaningfully to the body of scientific knowledge. Such motivations need to be exploited and reinforced during the project. From personal experience, I find the citizen scientists I work with value an opportunity to contribute to science that might make the world a better place, and an initial goal is to develop a narrative that supports this.

To connect effectively with the data collection process, participants need to be suitably trained, so that they are sure of what they are doing and

Box 4.1: UV-B Decomposition Bag Citizen Science Experiment.
An example of how the influence of UV-B on litter quality and litter breakdown across a large latitudinal gradients could be examined using mass participation citizen science.
Approach A common plant species grown under two UV environments will produce litter that decomposes at different rates. Citizen scientists grow their plants, harvest and weigh leaf material to make decompositions bags with two mesh sizes to exclude different decomposers. Bags are provided with three different materials on the upper size that (1) exclude UV-A and UV-B, (2) exclude UV-B but transmit UV-A, and (3) transmit UV-A and UV-B. The upper UV screening material will be perforated and held away from the litter bag so that it doesn't get marked nor cause condensation to accumulate inside the bag. Decomposition bags are sent out with a dosimeter or thermopile that quantifies the UV treatment that the bags receive over the course of the experiment. Dosimeters and thermopiles are a cheap way to quantifying received UV doses – see Beyond the Visible: Chapter 3 Quantifying Radiation p78-79. Participants harvest and weigh half the bags after time period 1 (e.g. 4 months) and the other half after time period 2 (e.g. 12 months).

why they are doing it (Bonney et al. 2009). Citizen scientist retention on the OPen Air Laboratories network (OPAL) was found to be as low as 10 % after initial online recruitment (Butt et al. 2013), so drop-off rates in some projects may need to be factored into project planning. Effective training can, however, enhance retention and ensure participants are well-motivated during their data collection, ensuring greater validity in the data collected (Dickinson et al. 2010). Citizen scientists can be trained in tasks with a range of complexities. The most simple citizen science data gathering exercise (e.g. counts of organism presence) may only need simple instructions from an online training page (www.bigbutterflycount.org). Such more-limited approaches are likely to be unsuitable for the complex ecological questions associated with UV-B research. Face-to-face training sessions enhance the complexity of potential data gathering techniques and are suitable for smaller groups of volunteers This personal approach has hidden benefits in ensuring participants have both a stronger commitment to the project and a better understanding of the science.

Participants are also incentivised to contribute by positive feedback. When working alongside participants, the lead scientist is a mentor who can constantly update on their progress and demonstrate what has been achieved. Social media platforms can provide additional feedback for mass-participation projects, delivering instant progress reports via the internet, or smartphones.

What can citizen scientists do?

Mass-participation citizen science projects using very simple data gathering methods give an appearance that simple studies are all that can be achieved. In practice, however, complex fieldwork tasks can also be undertaken with appropriate training. The citizen-science-led UK charity, Earthwatch, for whom I work, oversees a global range of environmental projects with different levels of scientific scope (Brightsmith et al. 2008). Our long-term monitoring project at Wytham Woods, Oxfordshire, uses teams of citizen scientist executives from a large multi-national company, who collect measurements from a network of forest-carbon-dynamics monitoring plots. These nine 1-ha plots, containing 12,000 trees were also originally set up by the volunteers. I am consistently impressed in how our volunteers can learn technical field skills rapidly and complete complex data collection methods. Field work tasks in ecology are often very repetitive, so the limiting step is often simply a case of person-hours – and teams of citizen scientists are ideal to provide this. Our citizen scientists have completed tree canopy leaf area index (LAI) assessments with hemispherical cameras, near-surface imaging of vegetation, and used infra-red gas analysers (IRGA) for measuring soil CO2 fluxes. In spring 2015, they helped construct a 48-plot drought experiment in the woodland, installing rainout shelters, soil respiration collars and rainwater collection bottles throughout 2 ha of woodland. Adaptable and creative field work and methods can enable inexperienced fieldworkers to be trained in complex tasks with minimal supervision. This project has now successfully engaged over 1 000 citizen scientists since 2006, with 8 papers delivered through international peer-reviewed journals.

What are the limitations of citizen science?

Citizen science can deliver both data and high quality public engagement for researchers, but the limitations of working with the public and managing teams of inexperienced citizen scientists can place constraints. Temporal or spatial biases can develop in datasets as a result of ad hoc data collection (Bonney et al. 2009; Roy et al. 2012), with such imbalances being minimised, either by changes in the experimental design or by statistical analysis adjustments. Mass public participation projects are more prone to this, in contrast to smaller projects where lead scientist mentoring minimises such problems. The validity of citizen science data has been repeatedly demonstrated in studies examining their quality (e.g. Butt et al. 2013; Crall et al. 2010, 2011). A critical part of the citizen science process, however, lies in error checking of datasets to improve their quality. Error checking will identify problems with individual data points (statistical outliers), or determine whether systemic biases exist in the data. Measurements taken by inexperienced citizen scientists will have lower levels of precision than those collected by expert scientists. This can introduce random errors are into the data, creating 'noise' through which a small environmental signal might be lost (Bonney et al. 2009). Using thousands of data points collected in Wytham Woods, Butt et al. (2013) compared volunteer citizen scientist measurements with those of expert scientists. Although volunteer measurements had significantly lower levels of precision, these were random errors attributable to a difference in means of less than 1 %.

Budgeting for citizen science projects needs to consider costs and losses of citizen scientist recruitment. Some materials may go to waste if participants fail to submit data. Citizen science programmes may require an unexpectedly large investment of the lead scientist's time spent training volunteers, or completing numerous administrative tasks. An important aspect to be addressed at every development stage is risk management and the need for participant safety. Experimental protocols may firstly need to be carefully assessed, not only to ensure scientific efficacy, but also to examine where any risk to participants lies. Protocols may need to be reviewed throughout the programme to manage risks as they develop. Pilot studies at the outset of a project are useful, where participants can be observed in action so that any unforeseen risks are identified and necessary adjustments made.

Figure 4.2: Earthwatch citizen scientists measuring tree growth rates from one of 12,000 trees in Wytham Woods, UK

Figure 4.3: Face-to-face contact with citizen scientists enables highly technical data-gathering methods to be used: here training in infra-red gas analyser (IRGA) use for carbon dynamics assessments in Wytham Woods, UK.

Moving forward with citizen science

In terms of UV-B research, citizen science has great potential value as a tool for collecting data along spatially-extensive natural UV-B gradients. Latitudinal transect studies, as used by the UV4Growth consortium (Hauser pers. comm.); Comont et al. (2012) and Ruhland et al. (2013), could be adapted for citizen scientists using simplified protocols. Regions, such as Europe, with large latitudinal ranges and high population densities, provide a clear opportunity for citizen science investigations on how large UV-B gradients influence plant ecology. Such studies could take the form of surveys, or common-garden mesocosms, to determine growth responses in key plant species. Photodegradation of plant litter by UV-B is another key area where latitudinal UV-B gradients be could utilised by citizen science experiments. A citizen science method developed by researchers at Utrecht University using the simple technology of tea bags as decomposition assays, is being used to provide a global assessment of decomposition rates in soil (Keuskamp et al. 2015). A similar decomposition assay method could be adapted to investigate UV-B impacts on above-ground decomposition rates via a UV-B latitudinal gradient and mass participation from citizen scientists (Box 1).

Citizen science is now an established and adaptable tool for researchers. It has growing scientific momentum and increasing validity as an accepted form of data collection. Effective use of citizen scientists comes from identifying opportunities for specific research that will engage the public. An array of citizen science models can be used to support diverse projects operating at a range of spatial and temporal scales, but practical limitations of the citizen science approach need to be recognised. Methodologies should be adaptive and subject to constant review based on participant performance. Citizen science is now embedded within many areas of ecology, but ecological UV-B research has so far been slow to take up this initiative. UV-B researchers now have an opportunity to develop new ways of working that will exploit the power of citizen science engagement and increase knowledge of the importance of UV-B in plant biology.

References

Bonney, R., C. B. Cooper, J. Dickinson, S. Kelling, T. Phillips, K. V. Rosenberg, and J. Shirk (2009). "Citizen Science: A Developing Tool for Expanding Science Knowledge and Scientific Literacy". In: *BioScience* 59.11, pp. 977–984. DOI: 10.1525/bio.2009.59.11.9.

Brightsmith, D. J., A. Stronza, and K. Holle (2008). "Ecotourism, conservation biology, and volunteer tourism: A mutually beneficial triumvirate". In: *Biological Conservation* 141.11, pp. 2832–2842. DOI: 10.1016/j.biocon.2008.08.020.

Butt, N., E. Slade, J. Thompson, Y. Malhi, and T. Riutta (2013). "Quantifying the sampling error in tree census measurements by volunteers and its effect on carbon stock estimates". In: *Ecological*

Applications 23.4, pp. 936–943. DOI: 10.1890/11-2059.1.

CEH, B. R. C. at (2015). *United Kingdom Butterfly Monitoring Scheme*. URL: http://www.ukbms.org/ (visited on 07/20/2015).

Comont, D., J. M. Abaigar, A. Albert, P. Aphalo, D. R. Causton, F. L. Figueroa, A. Gaberscik, L. Llorens, M. Hauser, M. A. K. Jansen, et al. (2012). "UV responses of Lolium perenne raised along a latitudinal gradient across Europe: a filtration study." In: *Physiologia plantarum* 145, pp. 604–618. DOI: 10.1111/j.1399-3054.2012.01591.x.

Crall, A. W., G. J. Newman, C. S. Jarnevich, T. J. Stohlgren, D. M. Waller, and J. Graham (2010). "Improving and integrating data on invasive species collected by citizen scientists". In: *Biol Invasions* 12.10, pp. 3419–3428. DOI: 10.1007/s10530-010-9740-9.

Crall, A. W., G. J. Newman, T. J. Stohlgren, K. A. Holfelder, J. Graham, and D. M. Waller (2011). "Assessing citizen science data quality: an invasive species case study". In: *Conservation Letters* 4.6, pp. 433–442. DOI: 10.1111/j.1755-263x.2011.00196.x.

Dickinson, J. L., B. Zuckerberg, and D. N. Bonter (2010). "Citizen Science as an Ecological Research Tool: Challenges and Benefits". In: *Annu. Rev. Ecol. Evol. Syst.* 41.1, pp. 149–172. DOI: 10.1146/annurev-ecolsys-102209-144636.

Gaberščik, A., A. Jones, and M. Jansen (2015). "Ultravijolično sevanje – pomemben dejavnik v življenju rastlin". In: *Proteus* 77, pp. 365–370.

Greenwood, J. J. D. (2007). "Citizens, science and bird conservation". In: *J Ornithol* 148.S1, pp. 77–124. DOI: 10.1007/s10336-007-0239-9.

Keuskamp, J., B. Dingemans, J. Sarneel, T. Lehtinen, and M. Hefting (2015). *Tea Bag Index*. Utrecht University, Ecology and Biodiversity. URL: http://www.decolab.org/tbi/protocol.html (visited on 07/20/2015).

OPAL (2015). *Soil and Earthworm Survey*. OPAL. URL: http://www.opalexplorenature.org/soilsurvey (visited on 07/20/2015).

Pocock, M. and D. M. Evans (2015). *Conker Tree Science*. URL: http://www.conkertreescience.org.uk/ (visited on 07/20/2015).

Protection of Birds, T. R. S. for the (2015). *Big Garden Birdwatch*. URL: http://www.rspb.org.uk/discoverandenjoynature/discoverandlearn/birdwatch/ (visited on 07/20/2015).

Roy, H., P. Brown, and R. Poland (2015). *United Kingdom ladybird survey*. URL: http://www.ladybird-survey.org/ (visited on 07/20/2015).

Roy, H., M. Pocock, C. Preston, D. Roy, J. Savage, J. Tweddle, and L. Robinson (2012). *Guide to Citizen Science. Guide to Citizen Science: developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK*. Natural History Museum and NERC Centre for Ecology & Hydrology for UK-EOF, p. 36. ISBN: 978-1-906698-37-9.

Ruhland, C. T., M. J. Dyslin, and J. D. Krenz (2013). "Wyoming big sagebrush screens ultraviolet radiation more effectively at higher elevations". In: *Journal of Arid Environments* 96, pp. 19–22. DOI: 10.1016/j.jaridenv.2013.04.005.

Sparks, T. H. and P. D. Carey (1995). "The Responses of Species to Climate Over Two Centuries: An Analysis of the Marsham Phenological Record, 1736-1947". In: *The Journal of Ecology* 83.2, p. 321. DOI: 10.2307/2261570.

Survey, B. G. (2015). my*Soil App*. NERC: the Natural Environment Research Council. URL: http://www.bgs.ac.uk/mysoil/ (visited on 07/20/2015).