Chapter 12
Can Citizen Science Seriously Contribute to Policy Development?
A Decision Maker's View

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ABSTRACT

This chapter considers the potential for citizen science to contribute to policy development. A background to evidence-based policy making is given, and the requirement for data to be robust, reliable and, increasingly, cost-effective is noted. The potential for the use of 'co-design' strategies with stakeholders, to add value to their engagement as well as provide more meaningful data that can contribute to policy development, is presented and discussed. Barriers to uptake can be institutional and the quality of data used in evidence-based policy making will always need to be fully assured. Data must be appropriate to the decision making process at hand and there is potential for citizen science to fill important, existing data-gaps.

INTRODUCTION

The research presented in this chapter has contributed to the European Union FP7 project COBWEB (EU FP7 reference number: 308513). COBWEB is a multidisciplinary citizen observatories project that aims to develop a data collection and sharing platform for crowdsourced or citizen science data, using standards and interoperability principles (Leibovici *et al.* 2015; Hodges *et al.* 2014). Contributors are mostly non-expert and can use this platform to customise their own data collection projects or campaigns, communicate with other contributors, and share and find data that are of interest to them. An overarching goal of the project is to enable the collection of data that ultimately can be sourced and accessed

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and used by policy makers; this data must be suitable, robust and of a known quality for evidence-based policy making. As such, the Welsh Government has been involved since the start of COBWEB and contributes the views of government and decision makers to the development of the project. The views presented in this chapter are based on the involvement of the authors in the COBWEB project, rather than a comparison of a range of structure data collection methods, and draws on personal experience in the policy development arena.

With respect to policy development, governments are interested in the quality of data, knowing where they came from, why and, whether or not the data are fit for purpose. Collecting environmental datasets on the geographical and temporal scales required to make informed decisions and to develop a broad and robust evidence base can be an expensive and resource costly exercise when employing traditional methods of data collection. Budgets are becoming more and more limited, and governments are increasingly open to innovative and cost-effective solutions to source reliable data (Haklay *et al*. 2014). Concurrently, mobile devices are becoming increasingly ubiquitous and more powerful, enabling ordinary citizens and volunteers to contribute more and more data about their local environments than ever before. Decision makers are acutely aware of the potential for these developments to significantly contribute to the 'data gap' and, increasingly, government papers are calling for more and more volunteer data (POSTnote 2014).

The importance of stakeholder engagement as a central precept to policy development and decision making cannot be overstated although it has been argued that the quality of decisions made through stakeholder participation is strongly dependant on the nature of the process leading to them (Reed 2008). Directly working with stakeholders, COBWEB presents the opportunity to explore and demonstrate effective methods of engagement with different stakeholder groups that are organising high volume environmental data collection projects. This is an opportunity for Welsh Government to learn effective measures to strengthen the interface between policymakers, citizens and scientists with the aim of educating, informing and communicating. The potential for citizen science as a method to stimulate local participation in environmental governance in line with the key themes of sustainable development is also an area of great interest to government.

The question that is being tested here is simply whether or not there is real potential for volunteered data on the environment, on the whole collected by the non-expert, to contribute to evidence-based policy making. If this is the overall goal of this work (and it is ongoing) then there are a number of objectives that contribute to answering this:

- To identify the main barriers to the uptake of projects like COBWEB.
- To develop strategies that can be applied to overcome these barriers.
- To incorporate effective stakeholder engagement to better align the objectives and applications of citizen science projects with those of the policy/decision makers.

BACKGROUND

The term 'citizen science' is used within this chapter to denote the collection of spatially referenced data and information by persons involved in on-the-ground environmental projects that use the internet to upload, manage or contribute that data to the wider public and other end-users for the greater good and

knowledge of others. The spatial component in this respect is directly related to the term 'volunteered geographic information' (VGI) of which there is a large body of scientific literature (Goodchild 2007). In many ways, citizen science data that are of a spatially referenced nature is indeed VGI (Haklay 2013).

In order to understand the value of citizen science data for policy development and decision making in government, the processes and concepts that underpin decision making or policy development in government must be understood. These processes not only provide a contextual backdrop to understand the value of citizen science but also provide insight into how the suitability of a piece of data or information can be assessed and considered to support or inform a policy or decision. Policy making can be a complex and dynamic process that is reliant on a range of factors or processes that seek to ensure that any decision, policy or intervention is based upon the best available supporting data, information or 'evidence.' The idea of evidence-based decision making is central to the concept of policy development, formulation, implementation and evaluation and in order to understand the potential for citizen science to add value to the decision making process, the mechanisms of how policy is created, developed and monitored must be understood.

WHAT IS 'EVIDENCE'

The Oxford English Dictionary defines evidence as: 'the available body of facts or information indicating whether a belief or proposition is true or valid' (Oxford Dictionaries 2013). This definition is at the heart of policy making within the contemporary governments of the UK and stresses the importance of providing supporting information or material in support of assertions, actions or statements. England's Department of for Environment, Food and Rural Affairs (DEFRA) suggests that evidence can have a broader definition:

'Evidence is the best available information used to support decisions in developing, implementing and evaluating policy, operations and services.' (DEFRA 2006)

With specific regard to environmental policy making within government, evidence can comprise a number of diverse types and forms, although the underlying theme that unites these elements is the use of the appropriate scientific methods in their collection, creation and synthesis. The following list provides an overview of the types of activities that are generally considered credible sources of evidence that are suitable to inform policy creation and development (DEFRA 2014):

- Research & Development
- Monitoring & Surveillance
- Secondary Analysis and Synthesis

This short list is not exhaustive and, of course, does not account for individual quality of research, analysis or monitoring exercises. Of note is the absence of unsynthesised data in a raw or primary state – this provides a broad but useful example of the separation of 'raw data' from the scientific collation, analysis and interpretation of the same. In other words, the production of evidence is more complex than the collection of data or information about observations or phenomena; the informed interpretation, analysis and contextualization of those data is where the real value for policy lies. These points must be considered where it is the case that citizen science aspires to contribute to policy development and the *evidence base*.

EVIDENCE BASED POLICY IN EUROPE

In 1999 the Modernising Government white paper noted the importance of robust and fit-for-purpose evidence in informing the creation of policies in the UK. It stated that Government 'must produce policies that really deal with problems that are forward-looking and shaped by evidence rather than a response to short-term pressures, that tackle causes not symptoms' (DEFRA, 2006). Since this declaration there has been a considerable shift of emphasis towards evidence based (or evidence informed) policy in the UK public sector. This can be seen in the creation of evidence strategies such as the Department for Environment, Food & Rural Affairs (DEFRA) Evidence & Investment Strategy 2010-2013 and the subsequent DEFRA One Evidence programme. Within Wales, and particularly within the environment sector, the evidence agenda has gathered considerable momentum and is of paramount concern in the creation, refinement and evaluation of policy and management of natural resources.

Within the European Union, a single unified concept of evidence based policy is less well defined. Evidence based policy has been defined as 'peculiarly British' (Solesbury 2001) but the concepts and elements involved are represented within guidance and policies created by the Commission and these are becoming increasingly prevalent in policy making discussions. For example in June 2014 the 2nd European Risk Summit titled 'Living in an uncertain world' focused on how EU and national policy-makers should communicate risk and formulate evidence-based risk communication in the health, food, environment and pharmaceutical policy areas. *Members of the European Parliament should take a closer look at how European agencies are handling risks and ensure that EU legislation is evidence based and risk informed* (Summit Chair Prof. Ragnar Löfstedt). Similarly, the 7th Environmental Action Programme (Decision No 1386/2013/EU) included as its fifth priority objective *to improve the knowledge and evidence base for Union environment policy*. The emphasis on the role of science and science based evidence as a way of increasing the effectiveness and accountability of EU legislation and the policies of member states is also supported by associations of professional scientists and researchers such as EuroScience (see www.euroscience.org).

In relation to environmental policy in Europe specifically, the need for scientific data relating to the state of natural resources is well documented. Projects such as the European Biodiversity Observation Network (EUBON) demonstrate the intention to more fully integrate biodiversity data into decision making at a range of scales. EUBON is explicitly linked to the 'Strategic Plan for Biodiversity 2011-2020' (see: www.cbd.int/doc/strategic-plan/2011-2020/Aichi-Targets-EN.pdf), in particular to the strategic goal: *By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning status and trends, and the consequences of its loss, are improved, widely shared and transferred and applied* (Hoffman *et al.* 2014). The application and integration of these data into environmental policies and legislation are key cornerstones of addressing biodiversity loss. They would form the basis of any measurement of trends, positive or otherwise and allow monitoring of strategies and the creation of milestone targets.

From these statements, the importance of the availability and collection of evidence as a driving force in the creation of strategies and policies is clear. Whilst the process may be less overt, and arguably have a less structured form than as laid out in UK policy development, the consideration of evidence, scientific advice and abstraction, trend analysis and effective communication are shared concerns. Whereas it should be noted that the evidence based policy process can be seen as a conceptual ideal it does ensure the consideration of key factors that surround and influence the uptake of research, data and information

as sources of evidence by policy makers. These factors are common to any consideration of the use of evidence to support decision making in the UK or further afield.

THE RELATIONSHIPS BETWEEN CITIZEN SCIENCE AND EVIDENCE-BASED POLICY DEVELOPMENT

Good evidence comes initially from good data. In its simplest case data are the measurements and observations from which evidence is abstracted. Data collection exercises themselves need to be robust and appropriate and the survey design needs to be configured to answer the question in mind. Difficulties for the decision makers come when the only data available is not quite appropriate to the policy question at hand. The use of data collected for another purpose raises questions about their application and use outside of the context and reason for which it was originally collected. That, coupled with sometimes significant issues around data currency can add ambiguity, or negatively affect confidence levels of evidence provided.

How does citizen science derived data fit into this framework of good evidence and add value to policy and decision making? Certainly data, when viewed in isolation, are not a suitable source of evidence for use in decision making. It is not appropriate to think that data collection in and of itself adds value to decision making. It is clear that, in order to realise the value of citizen science in a policy context, any data collection should be scientific and adhere to the principles of good study design (Wiersma 2010) and, in addition, that the data collection method and its subject will be appropriate to fit a pre-defined policy question or need.

The appraisal of evidence and whether or not specific types of information are indeed 'evidence', has to be regarded within a social and political context (Nutley *et al.* 2013). A wide range of variables exist that can affect any judgement of whether evidence is appropriate for policy making outside of study design. Evidence that is persuasive or actionable in a practical way can be attractive to a policy maker (Cameron *et al*. 2011) and similarly, implications of real world considerations such as timescale or availability of resources can influence the adoption of different evidence gathering activities; the latter factor being particularly relevant across all member states and even globally at the time of writing. This leaves considerable opportunity for innovation and development within this area both technologically and conceptually.

Although the *commissioning* of evidence creating activity (be it research, monitoring or evaluation or other analytical processes) needs to demonstrate appropriate degrees of scientific rigor, there remains considerable scope for innovation to transform traditional concepts of *good* evidence and to further contribute to developing an understanding of the theme which the evidence or research is investigating (Sanderson 2009). That is not to say that the large scale uptake of citizen science derived datasets into the decision-making process would be a straightforward process. Evidence derived from these sources would need to convince policy makers, assessment panels or evidence specialists that it was appropriately conceived, designed, implemented and analysed and that it was suitably aligned with the intended purpose for its use or policy outcome. Each project would need to instil sufficient confidence that the findings or data are suitable for use. The greater the confidence in the evidence under consideration, then the greater the chance that it will be drawn upon to support decision making and policy development.

Technological, methodological and conceptual innovation are all vital to driving the collection of new data. For the policy maker or decision maker the ultimate benefit of such innovation would be the

subsequent production of more robust, timely and appropriate evidence. The need for new data is increasing and the reality of a dynamic and shifting policy landscape adds additional pressure on the ability to gather data on new themes, in new and efficient ways. It is into this situation where citizen science offers real potential, especially when delivered by utilising internet and mobile technologies as proposed by COBWEB (see also http://www.citizen-obs.eu/). The adoption of any new technology or approach however, will bring with it a set of issues and conditions that need to be considered in order for it to be of value to policy and decision making. This potential needs to be balanced against the primacy of the use of citizen science approaches to answer predefined questions and framed within effective study design as part of a scientific exercise (a research project or a monitoring programme for example). It is when the potential of approaches like citizen science are framed within the context of 'good' evidence where they offer most value.

INITIAL CONCERNS AND CHALLENGES

In order to increase accuracy and confidence in data collection exercises the use of validation and quality assurance methods are widely considered important, if not essential to the validity of citizen science projects (SCU 2013; Delaney *et al*. 2008, Gollan *et al*. 2012). It follows that this advice aligns with evidence assurance practices too, where data quality plays an important part. Therefore an appreciation of the occurrence of bias in the data must be addressed. This is not to state that any dataset will be expected to be free of error or inaccuracies but it is important that there is an awareness or understanding of types of issues to enable specialists and decision makers to take into account these potentially misleading factors.

Appropriate study design can mitigate or address bias in data; detailed and comprehensive metadata becomes a key factor in contextualising datasets for evidence assurance exercises to reduce the risk of inappropriate usage of data, particularly here where a failure to recognise bias in reporting could lead to the misapplication of effort or resource and affect any subsequent evaluation or measurement of impact of that effort. In other words, it is as important for policy and decision making that data is of a *known quality* as it is for any scientific subject matter. The documentation of quality assurance practices and the supply of data quality statements will add value to citizen science derived data and improve its uptake and use/re-use especially in light of the reluctance to use data of unknown provenance by scientists (Alabri *et al*. 2010).

The GPS functionality that is available in mobile devices offers great potential for the collection of spatially referenced information by the relatively non-expert user. With many available applications or 'apps' this can be captured with the observation in an automated way without input from the user. This process reduces the risk of error in the transcription or recording of abstract coordinate references, especially in the case of non-expert users. There can be inconsistency in the quality of GPS derived spatial references however, and this can have subsequent impact on the accuracy of a particular observation (Meek *et al.* 2015). If information on the 'known quality' of observations can be recorded along with the observation itself this can have profound implications on the reuse of those data and the potential for its use in the policy and decision making process. This is an area of research that is being explored as part of the COBWEB project as well as the incorporation of other quality assessments that will assist the end-user in judging whether or not that dataset might be fit for purpose with respect to the policy question or evidence requirements being considered (Wiemann *et al* 2015, Meek *at al* 2014).

Quality has long been a contentious issue with regards to citizen science derived or VGI datasets with numerous references in the available literature (Flanagin & Metzger 2008). The main thrust of discussion is whether observations and recordings made by non-expert citizens are as accurate as those made by specialist or professional recorders. With regards to evidence informed decision making this issue is particularly pertinent; generalised statements about the quality of *citizen science data* on the whole cannot be made due to the diversity in project approaches and subjects addressed however it is acknowledged that *Citizen science can yield high quality, policy relevant information* (Haklay 2015). Certainly a goal in COBWEB is the process of attributing a known confidence to the observation made or the set of observations collected by any one survey as well as to filter observations based on this or any given parameter such as an acceptable numerical range; it is believed that given the ability to effectively interrogate the observations and/or to access the observations and dataset *after* they have already been conflated with authoritative data sources for example, will result in uptake of those data for use in policy making.

The complexity of the survey or data collection process or protocol is another area that is of a concern. This can greatly influence the quality of observations and their recording as well as influence the popularity or uptake of the survey. Pocock *et al.* (2014) rightly note that there appears to be a relationship between complexity of the survey protocol and the number of participants that may be motivated to take a project, this has also been seen during the 'co-design' phase in the COBWEB project (see below). This can impact on the statistical validity of a given data set if too few records are submitted, or potentially threaten the longevity of a project if the protocol is so demanding as to become a barrier to participation. It also follows that projects that require complex observations of particular phenomena may be associated with a higher level of erroneous recording by non-specialists (Dickinson *et al.* 2010). This can be mitigated to a degree by the production of supporting materials or professional specialist support in identification exercises.

STAKEHOLDER ENGAGEMENT: THE BENEFITS OF GOOD ENGAGEMENT PRACTICES

Embracing the concept of government engaging with citizens through citizen science projects not only raises the potential of enriching the evidence-base with fit for purpose data of a known and acceptable quality, but there are also additional intangible benefits. The importance of engagement, participation in governance and the communication of knowledge and development of skills are important aspects of sustainable development (SD). Informed and politically active citizens can play a crucial role in the success of local, national and global policies by playing a significant part in the development of policies (Irvin and Stansbury 2004). In the literature this type of VGI where the public can contribute to the decision making process of government is often referred to as 'public participation GIS' or PPGIS (Kingston *et al.* 2010, Ganapati 2011) though there are some notable differences between the two (Tulloch 2008). Citizen science provides this potential for government to engage with citizens in a practical and meaningful way, contributing to knowledge and skill development and providing the potential for *additional value* to be gained from being involved in these early stages of evidence gathering.

Shirk *et al.* (2012) suggest the need for 'deep collaboration between stakeholders in the early stages [of project design] to achieve environmental policy and management goals.' This deep collaboration should ideally allow for the balancing of the aims, objectives and motivations of those commissioning/

designing the project, be they scientists, policy makers or motivated individuals, and those who will be participating in the project. This deep collaboration also aligns well with the political need to engage meaningfully with citizens and to encourage and value input and participation in issues of interest to them. Of course other factors play key roles, such as trust building and the development of shared and committed understanding (Ansell and Gash 2008). In the case of COBWEB, stakeholders (project designers, scientists, citizens and policymakers) aim to look at the creation of a project together, in order to make it more effective. Effectiveness in this sense comes from the balancing of scientific, educational, motivational and practical elements. Keys to this process are the establishment and agreement of a shared vision and of increased levels of mutual understanding between all stakeholders that take into consideration the different perspectives and expectations of those involved.

Co-design and co-creation of projects is a growing theme in the research community in the consideration of citizen science and digital innovation. It is referred to frequently in the Socientize Green Paper on Citizen Science (Citizen Science for Europe: Towards a better society of empowered citizens and enhanced research see: www.socientize.eu/?q=eu) where it is noted that co-design in citizen science bridges the gap not only between policy and citizens but also increases understanding between scientists/research community, citizens and policymakers as a whole. This increased understanding has the potential to not only increase the relevance of research to policy makers by strengthening the science-policy interface but also to increase the value and engagement with citizens and society with the aim of influencing the research agenda to maximise societal value of research outputs. This cross-sectoral dialogue provides a compelling opportunity to embody core principles of SD in policy creation through the use of citizen science projects, particularly in relation to the environment as well as to help target the effectiveness and sensitivity of policies and research at local (and wider) scales.

The co-design process can be considered key to ensuring the sustained motivation of stakeholder involvement. The success of a citizen science project may rely on having a critical mass of recorders (human sensors) to collect, analyse or review an appropriate amount of data. Motivation can be effected by many factors within both the design and implementation of a citizen science project. UK Environmental Observation Framework's 'Guide to Citizen Science' (Tweddle *et al*. 2012) note the importance of having motivated, interested and keen participants as a primary factor in any citizen science exercise. It follows that any such project should have, as a core objective, an effective mechanism or strategy to motivate and retain participants. Failure to successfully secure a group of enthused, motivated and able (or enabled) participants can have a direct impact on the quality, quantity and longevity of the data or data series collected and ultimately, of course, the scientific success of the project itself which in turn, will have an impact on the potential for that data to be reused in policy development.

Citizen science can positively effect and influence more sustainable behaviours or attitudes in citizens and communities and allow a more informed dialogue with stakeholders as part of the democratic process. Furthermore, the potential for citizens to participate in projects that generate data that could well contribute positively to local, national and global issues, e.g. biodiversity loss or the spread of invasive/non-native species. Gollan *et al.* (2012) suggest 'citizen science has the potential to bring society closer to science and to nature, bringing about a sense of ownership and helping create the kind of society that works to protect its natural environment' (SCU 2013).

If citizen science can affect behaviour positively then its usage may provide a meaningful way not only to engage with citizens but also to empower and enthuse them through participation in specific projects and/or events. The citizen engagement elements stressed under SD principles can be supported through the use of citizen science type activities not only through establishing a novel and engaging method of

communication, education and knowledge exchange between public authorities (or the scientific community) but also through positive action in the participation of environmental science to contribute to the understanding and management of our natural resources. Access to and distribution of these data online provide a tangible presence of the effort of individuals or groups to provide evidence to scientists and policy makers to ensure that they have access to the best available data and information to support their respective research or responsibilities.

The extent to which citizen science can alter behaviour, effect societal change and increase awareness is hard to measure (SCU 2013). The education value from citizen science can vary depending on the project, the complexity of the protocol and the level of resource available to provide contextual and educational material. However the ability of citizen science to encompass a means to provide an engagement mechanism, to encourage participation in science and enable the collection of data to support and effect policy development align well with the concepts of effective policy making and will require further scrutiny as citizen science continues to develop.

MAKING DATA MORE AVAILABLE

The ability to understand the context and make up of a project, its objectives and aims and the provenance and quality of its data and outputs is captured in the metadata associated with the data created by that project. Structured and standardised metadata allows a rich test environment to determine the suitability of a dataset for communicating key concepts, metrics and narratives. The role of metadata for communicating essential contextual information for spatial information is a primary factor that underpins the establishment of an infrastructure for spatial information through the European driven INSPIRE Directive (see: http://inspire.ec.europa.eu/). The definition below is taken from the Access to European Law website (See: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32008R1205).

The definition of a set of metadata elements is necessary in order to allow identification of the information resource for which metadata is created, its classification and identification of its geographic location and temporal reference, quality and validity, conformity with implementing rules on the interoperability of spatial data sets and services, constraints related to access and use, and organisation responsible for the resource. Metadata elements related to the metadata record itself are also necessary to monitor that the metadata created are kept up to date, and for identifying the organisation responsible for the creation and maintenance of the metadata.

The importance of metadata, for the policy maker, is its potential to communicate this contextual information effectively and concisely to improve the assessment of its suitability for any subsequent use of the data. Consequently, this will increase any confidence levels that are appropriate in design and output. The use and potential extension of current metadata standards tailored to citizen science projects could provide additional value here to allow the often complex spatial and temporal variability in citizen science projects, concepts and records to be made more understandable and transparent to the user. The use of metadata and established spatial data infrastructure (SDI) initiatives to increase accessibility, openness and support the use and uptake of data across a multiplicity of scenarios also provide additional value to decision makers. The use of controlled vocabulary and terminology and a standardised approach to recording and displaying metadata to published standards allows the assessment of key project details

in an informed way. This can be seen as a method of further contextualisation to allow consideration of utility of the data in a familiar and rich digital environment.

The many variables at play within any given citizen science project can greatly affect the quality and accuracy of the outputs. Metadata should provide valuable insight into these variables which can lead to an increase in the likelihood for that data to be reused appropriately and with a measured level of confidence. The varying ways that quality can be affected (and potentially defined) at record, dataset and project level and at the time of capture (user experience and on-site verification to name just two) present a complex set of situations which may need to be understood. If these situations can be summarised to reduce ambiguity and support the notion of a *known quality* then the data derived has an increased chance of being used appropriately and effectively within policy development and decision making.

The publication of data with appropriate metadata and additional information that contextualises the quality of that data not only has the potential to stimulate its uptake within government (and government commissioned projects and research) but also to stimulate its use within the wider context of the environment sector. Increased access to more inclusive or accurate environmental data provides countless opportunities to positively stimulate targeted and informed research, activities and technology. Release of information at required quality levels can improve local, national and wider reporting effort, making any derived outputs more representative of real world phenomena.

The ability to publish standardised data of known quality digitally and potentially across established key environmental data repositories improves access to data for re-use and also increases transparency of the reasoning behind decisions and the evidence supporting those decisions. The democratic benefit to increased understanding of how and why decisions have been made and the evidence upon which those decisions have been based are potentially great and strengthen the concepts of openness espoused under sustainable development principles. An important point here may be the use of standards to share and discover data held within these repositories. The COBWEB project has worked on the development of a profile of the relevant OGC standards to maximise interoperability known as 'swe4citizenscience 2015' (further information on github: https://github.com/opengeospatial/swe4citizenscience/wiki/What's-this-all-about). This has resulted in progressing a vision of a common data model, to which data can be published using OGC web services; with sufficient community support, citizen science type data can be published to this open standard. This will then increase the immediate usefulness of these data and allow the myriad of potential users of such data to exploit existing standards based tooling and develop new standards based solutions (Higgins *et al.* 2015).

The use of digital infrastructures to publish and promote access to environment data, concepts and methods could facilitate or support more sharing of data and methods especially when supported by online digital communities that allow collaboration of stakeholders across a range of geographical areas. This improved picture will in turn benefit future and present decision making by allowing a more representative picture of the environment or issue to be presented. This may be used to improve the effectiveness of lobbying or be incorporated and captured in dialogue with stakeholders as part of the policy creation process.

FUTURE RESEARCH DIRECTIONS

The need for practical and effective links between research and policy to effectively tackle key environmental and social issues is a growing area of interest in the research community: 'Close collaboration

is essential between the scientific community and stakeholders across the public, private and voluntary sectors to encourage scientific innovation and address policy needs' (Future Earth, 2013). The overall aim of this effort toward closer collaboration is to target research outputs to reflect societal and environmental needs and to support and inform policy development to incorporate the latest science and knowledge.

The involvement of Welsh Government in the COBWEB research project can be seen as an example of the strengthening of this science/policy interface. Given that the aims and objectives of the researchers and policy makers within the consortium can be quite different, the closer working and improved dialogue between these parties helps concentrate effort and activities to communicate the potential of new ideas and science and to test or ideally realise that potential to support the tackling of real world problems or concerns. For COBWEB, the agreed use of a co-design model to develop, refine and test technology and systems, assess their policy applicability and usefulness in the real world is a further benefit and strengthens not only the science/policy interface but also the interface between these two parties and citizens, community groups and volunteer organisations (real world actors). This collaboration supports the potential for this research project to provide valuable project outputs to stimulate and support local community, research and policy agendas.

If datasets gathered from citizen science projects are to realise their full potential as a source of evidence for policy and decision making there are a range of potential issues that need to be examined that relate to the expenditure of *resource* (in time, effort and financially). Co-design is certainly a promising way to bridge gaps between science, community and governments but it does not come without a cost. Full cost-benefit analysis studies in this area would be useful information for government departments in their planning of involvement with citizen science projects particularly where there is a co-design element. Input will be required in terms of time and expertise, resources and other material, possibly publications can be required and there will be overall management costs in these interactions. These costs can be far outweighed by the potential tangible and intangible benefits of government involvement in these projects but justifications will have to be made.

As citizen science can be seen as the involvement of volunteers in science (Roy *et al.* 2012) the source of risk or uncertainty in a project's longevity or quality can rely on a range of complex factors that revolve around a project's ability to recruit and retain a team of citizen scientists. The success or failure of a citizen science project can depend on this potentially unknown variable and it should not go unmentioned. This uncertainty could reduce the desire in the commissioning of citizen science projects specifically by policy makers if the need for representative levels of high quality data is a primary factor in the delivery of a policy. This may be especially the case for contributory or collaborative projects (terminology from Bonney *et al.* 2009) that may have disconnect from potential participants. Further understanding of ensuring the long term viability of these projects is an important area for research and an area where government would like reasonable assurance that any investment made will make a positive and effective return and will be a good use of public money.

CONCLUSION

The value of citizen science projects to contribute to the 'evidence-base' for decision making and policy development lies in its ability to harness the effort and knowledge of contributors to produce data and information. The process of decision making and policy development requires the careful consideration of the *suitability* of potential sources of evidence. Confidence in that data is a key component that will

determine whether or not that data or information will feed into the policy development process. Data or abstracted information from a project that is well conceived, designed and implemented and produces data of suitable quality and quantity has a greater chance theoretically of being considered as a serious potential source of evidence. Geographical and temporal scales are also variables that need to be considered. Challenges arise when there is any degree of mismatch between the data that are required to fulfil a specific policy need and the data that are available through a vast number of very different citizen science projects.

The use of co-design as a method of deep collaboration with stakeholders involved in a citizen science project presents opportunities to further add value and confidence to the data collected for use in decision making. Through co-design the different elements of a project can be discussed and agreed and it is at this point where a mismatch can be avoided with respect to what data are required and what data are produced, in other words, better aligning project design and outputs to policy needs and/or priorities. In addition, this approach may help reduce risk to delivery through the valuing and incorporation of local knowledge and motivations, factors noted as important to effective and successful projects. Understanding motivation as a barrier and opportunity for better and more effective engagement is an area of research in citizen science that would be welcomed by anyone who wishes to invest time and resources into this area.

Pressure on resources and the drive to gather evidence to inform new and increasingly complex environmental scenarios and management systems brings the value of citizen science based environmental data collection into sharp focus. The concept of citizens' observatories is an important advancement in recent years as undoubtedly there is vast potential to use these rich data sources in the area of policy development and decision making. Working directly with groups contributing to these citizens' observatories however can be resource costly and it does seems unlikely that for every policy that requires data, appropriate resourcing can be targeted to coordinate and manage co-design projects with interested stakeholders. It is expected that as the concept of citizens' observatories develops, more and more citizen science projects with a co-design element that is supported by the public sector will be seen. It will only be a matter of time that government will utilise this data but it will always need to demonstrate sufficient quality and relevance to the policy or decision making process in hand.

Technological and conceptual innovation can add value to citizen science by utilising a range of sensors present within mobile devices (or from the sensor web) to measure and collect data about environmental conditions to enhance or assure observations interpreted by human sensors. This kind of data will no doubt increasingly contribute to citizens' observatories. Effective software design can assist standardised data capture routines that reduce the risk of transcription error and help facilitate automated quality measurement exercises. These processes can contribute to identifying *known quality* and communicate contextual information through the production of meaningful metadata. Conflation with authoritative datasets and attributing citizen science data with measures of quality will no doubt increase confidence levels in the uptake of such data as suitable sources of evidence and increase the likelihood of this data contributing to the policy development process. The area of data quality with respect to citizen science data is a known barrier to uptake in government but it is expected that as methods are developed to automatically or semi-automatically assign known levels of confidence to that data, potential users will be more informed of the suitability and reliability of that dataset; with known and acceptable levels of quality will come greater and broader uptake.

Data quality will always need to be assured and this is an ongoing area of research that will be closely watched by those hoping to use citizen science data more prolifically. Data accessibility and availability

will also be a key factor in how extensively this kind of data will be used in government, the data must be easy to find and ideally be made available to data streams already accessed by those sourcing data that will contribute to the *evidence-base*. Our expectations is that citizen science data *can* contribute to the policy development process but in order to do so it will always have to assure the user that it can be fit for purpose, robust and timely. As momentum gathers in the development of citizens' observatories and as opportunities for collaboration are increasing (Haklay 2014), uptake of this sort of data in government and amongst decision makers and policy makers will no doubt increase. Undoubtedly there will be institutional cultures that will need to adapt (Brabham 2013) and change always takes time to develop fully but there are plenty of practical benefits associated with engaging with the development of citizen projects, particularly if these are on a large scale. In addition are the intangible benefits associated with empowering citizens, better environmental stewardship and fostering understanding between science, community and government.

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