20

# Citizen science in environmental protection agencies

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In: Hecker, S., Haklay, M., Bowser, A., Makuch, Z., Vogel, J. & Bonn, A. 2018. *Citizen Science: Innovation in Open Science, Society and Policy*. UCL Press, London. https://doi.org/10.14324/111.9781787352339

## Highlights

- Environmental protection agencies (EPAs) in Europe and the United States are increasingly making use of citizen science for environmental protection, including engaging the public and awareness-raising, empowering action by communities, monitoring and data collection, and providing sound evidence on which to make decisions.
- To increase the impact of citizen science for environmental protection, improvements are needed in data management and infrastructure support, communication of data quality, sensor development and communication with citizen science data providers.
- Innovations in technology and organisational practices are enabling a citizen-agency dialogue based on good data and feedback on use of evidence. Citizen science has the potential to transform environmental protection by inviting the public to work with agencies to generate knowledge and find solutions.
- Effective case studies include citizen scientists acting as an agency's 'eyes and ears' (see box 20.2, Improving the effectiveness of sentinel systems: Irish Environmental Protection Agency) in addressing local environmental matters, including identifying environmental concerns for additional research and action (see box 20.3, Regulatory action spurred by citizen science: The Clean Air Coalition of Western New York and Tonawanda Coke Corporation); Promoting environmental education in schools (see box 20.4, The Enviróza school programme); and further legitimising the high-level strate-

gic delivery of a responsible authority's environmental protection mandate (see box 20.1, From Opportunism to a Strategic Approach: Scottish Environment Protection Agency [SEPA]).

## Introduction

Citizen science has the potential to transform environmental protection by involving the public in work with agencies to generate knowledge and find solutions (Shirk & Bonney; Ballard, Phillips & Robinson, both in this volume). Environmental protection agencies are increasingly turning to citizen science to assist in the achievement of environmental protection (Hindin 2016; NACEPT 2016); and innovative technology is enabling more citizen-agency dialogue and feedback on use of evidence (Wiggins & Crowston 2015; Novak et al. in this volume). Environmental protection agencies in Europe and the United States have protection of the environment as their primary responsibility. In addition to that overarching mission, key policy drivers often include encouraging the wise use of resources, protecting public health and enabling sustainable economic development. This policy balance is critical, particularly as defining sustainable economic growth in an environmental context can be challenging, especially in respect of resource use and disposal of waste. Environmental protection agencies rely heavily on good-quality evidence about the health of ecosystems, pressures on these natural resources and the effectiveness of regulatory and other interventions. This chapter demonstrates that citizen science has an increasingly important role in providing evidence, raising environmental awareness and empowering the public (Nascimento et al.; Smallman, both in this volume). The case studies as presented reflect examples of how EPAs are increasingly making use of citizen science to engage the public in environmental issues and provide sound evidence on which to make decisions.

## Citizen science and community science

Citizen science is incredibly diverse (Wiggins & Crowston 2015), and the diversity of citizen science approaches is evident when looking at the types of projects that EPAs are involved in; these include air and water quality monitoring, collection of baseline data and identification of hotspots, networks of sensors, environmental justice efforts, educational projects, public engagement and more (boxes 20.1 to 20.4; NACEPT 2016).

The diversity of environmental citizen science is reflected in how – and by whom – projects are initiated and implemented. Often, citizen science projects are contributory in nature in that they are initiated and defined by an institution or researcher within an institution (such as an EPA), who then solicit input and participation from members of the public (boxes 20.1, 20.2 and 20.4; see also Novak et al.; Ballard, Phillips & Robinson, both in this volume). For example, the volunteer rainfall observation network in Scotland is driven by the objectives of the hydrometric network in the Scottish EPA and UK Meteorological Office. Although EPAs often initiate and implement projects that directly support the priorities of the agency, they also often encounter projects that are initiated and defined by the goals of community members, who may work independently or in collaboration with scientists but maintain ownership over the entire scientific process (Dosemagen & Gehrke 2016). Although this chapter includes these projects in the definition of citizen science, the terms 'community science' (e.g., Dosemagen & Gehrke 2016) or 'community citizen science' (e.g., NACEPT 2016; Chari et al. 2017) are also used to describe this type of project. The Angler's Riverfly Monitoring Initiative in the UK (The Riverfly Partnership 2017) is one example where an interested and concerned community group has acted as the main driver for monitoring environmental quality. Community goals are usually rooted in a specific environmental issue and often related to environmental justice; most often, communities identify a local environmental issue, work to understand that issue, and then use that understanding to advocate for improvements to local environmental and human health. The goals of these projects can include increased regulation and enforcement of violations, and communities often approach EPAs or other government organisations for help in achieving their goals (box 20.3).

## Uses of citizen science by EPAs

Analysis of citizen science initiatives among EPAs in the European EPA Network and in the United States reveals several principal goals.

### Education and awareness-raising

Many projects emphasise the value of environmental education and scientific literacy for both children and adults, especially in providing participants with an understanding of the places where they live and work

(Haywood 2013; Newman et al. 2017). Citizen science also supports a shared understanding of the importance of environmental protection. There are many current examples of EPAs encouraging citizen science activities to raise awareness of environmental issues such as the identification of contaminated land sites in Slovakia (see box 20.4: Enviróza school programme), the recording of invasive riparian plants in Scotland (Plant Tracker) and the mapping of toxic algal blooms by the South East Alaskan Tribal Toxin partnership in the United States (NACEPT 2016). Participants of citizen science projects often also educate their local communities. For example, both students and teachers that participate in the Enviróza school programme are able to share their knowledge of contaminated sites with their families and communities (see also Peltola & Arpin in this volume).

## Empowering action by communities

Knowledge and evidence of environmental issues can be powerful motivators for community action to directly address an issue or exert pressure on governments to take action or reprioritise resources (box 20.3). For example, litter data from organised litter picking campaigns such as 20 years of data from the UK Marine Conservation Society's Beach Clean (Marine Conservation Society 2018) empower communities to conduct dialogue with sewage treatment companies and manufacturers of litter-related products. Similarly, the Great Nurdle Hunt is a citizen science project organised by an environmental charity in North East Scotland which collects data on the prevalence of nurdles, pre-cursor plastic pellets, in the strandline of beaches (FIDRA 2018). This simple monitoring scheme has now extended across the UK and parts of Europe. The evidence of nurdle pollution has led to Operation Clean Sweep (OCS), an international programme originally designed by the plastics industry and supported by The British Plastics Federation and PlasticsEurope. The OCS manual provides practical solutions to prevent loss for those who make, ship and use nurdles with the key message that good handling practice can easily reduce pellet loss.

Citizen science can also contribute to positive interactions between EPAs and the public (see also Sforzi et al. in this volume). Beyond education and data collection, citizen science can allow for the development of a shared agenda with members of the public for environmental protection. Encouraging public input and open collaboration and responding

to community concerns means that EPAs demonstrate a commitment to serving the public and investigating their concerns and priorities. Citizen science can thereby provide opportunities for local, regional and national action that will improve environmental protection – from individual action to national policy. This facilitating role for citizen science can be beneficial for both members of the public and EPAs, which gain recognition of their environmental protection mandate through public participation.

## Monitoring and data collection

Generally, data generated through citizen science has been met with scepticism by professional scientists and policymakers (Kosmala et al. 2016; Bonney et al. 2014), but recently more EPAs have come to regard such data as potentially contributing significantly to evidence needs. Volunteer monitoring has a long history in EPAs – in the case of rainfall measurement, this extends as far back as the early twentieth century. Other examples include discerning biological indicators of water quality and pollution incident recording. In some cases, as in rainfall observing, the quality of data recording has consistently met recognised quality standards over many decades; in other cases, the quality of data has improved markedly over the past two decades (Crall et al. 2011). Furthermore, modern sensor technology has enabled more technically demanding measurements by interested members of the public, as in recent air quality monitoring surveys in The Netherlands (see also Volten et al. in this volume). This data is proving to be genuinely useful to the relevant Dutch environmental authority (Snik et al. 2014).

Citizen science can invigorate environmental research by generating data that allows for a deep understanding of environmental quality and environmental issues (Hampton et al. 2013). Citizen science is uniquely suited to some areas of research and in some cases it is the only option. For example, by harnessing the contributions of people all over the world over long time periods, citizen science can provide datasets with rich complexity over space and time (McKinley et al. 2015). Citizen science can also fill in gaps in environmental information, including issues that are currently not regulated, such as the emergence and spread of invasive non-native species (see also Nascimento et al. in this volume). Finally, citizen science can allow EPAs to better understand priority issues like climate change. For example, Evolution MegaLab invites the public

to record phenotypic variation in garden snails hypothesised to be driven by temperature changes and regional climate change (Evolution MegaLab 2018).

## Influencing decision-making and policy

Although the link between public participation in environmental activities and policy-making is not well established (see also Nascimento et al. in this volume), the connection to decision-making in EPAs has become stronger in recent years (McKinley et al. 2015; Haklay 2015; McElfish, Pendergrass & Fox 2016). Public campaigns backed by evidence generated through citizen science can strengthen their influence on government, national agency and local authority policy-making and policy implementation. Examples from the European EPA Network include air quality strategy in The Netherlands (see Volten et al. in this volume), controls on the fly-tipping of waste (for example ZeroWaste Scotland) and many more (see boxes 20.1 to 20.4). Citizen science approaches can be a powerful tool for identifying emerging issues and developing solutions through new knowledge generation, for example, in water resource management and the assessment of human impacts in remote regions (Buytaert et al. 2014). The approach can be especially useful in crisis situations when community or advocacy groups work to initiate government action on a specific issue (Conrad & Hilchey 2011; box 20.3).

## Advantages and challenges

Citizen science is cost-effective, but it is not free (Shirk & Bonney 2015; see also Danielsen et al. in this volume). However, investment in citizen science can have significant impact and progress can support citizen science contributions to environmental protection (Geoghegan et al. 2016; NACEPT 2016), especially when that investment helps maximise the advantages of citizen science and overcome the following challenges. For many of these advantages and challenges, the European Citizen Science Association's Ten Principles of Citizen Science are a useful guide (ECSA 2015).

## Data management and infrastructure support

Many citizen science initiatives suffer from a lack of infrastructure to efficiently hold, manage, analyse and interpret citizen science data. This is true especially where resources are limited, which particularly includes community initiatives. This has hampered the usefulness of many citizen science projects where the aggregation of data is of key importance (see Williams et al. in this volume). Environmental protection agencies can help by providing resources to enable the construction of data management tools and facilitating their use, or by providing easy access to tools that are already available. The Scottish EPA is addressing this by developing a web-based platform for handling citizen science initiatives (box 20.1). Investment in data management tools will greatly improve the potential for data sharing between projects and between projects and agencies (see also Sforzi et al. in this volume).

## Communication of data quality

EPAs and other institutions are often reluctant to accept and use citizen science data due to an implicit assumption that citizen science data is inherently of lower quality than traditional science data (Kosmala et al. 2016; Bonney et al. 2014). There are several strategies to ensure appropriate data quality to enable the use citizen science data for environmental protection (see also Williams et al. in this volume):

1. Citizen science projects can integrate multiple mechanisms to ensure high-quality data from participants (Wiggins et al. 2011; Freitag, Meyer & Whiteman 2016).
2. Providing extensive metadata allows citizen science projects to communicate the 'known quality' of the data so that it can be used appropriately by EPAs (Bowser, McMonagle & Tyson 2015).
3. EPAs can create standards for data quality and communicate the quality of data needed for different purposes. Citizen scientists can produce 'data fit for purpose' through careful project design in communication with representatives from EPAs (Wiggins et al. 2013; Roy et al. 2012; NACEPT 2016).
4. EPAs and organisations involved in citizen science can engage in partnership strategies and approach a problem with a combination of professional data collection and citizen science (NACEPT 2016).

## Sensor development

Recent development of advanced monitoring techniques has opened up possibilities for citizen science to include measurements from low-cost, portable, small sensors to monitor air and water quality. However, the individual performance of these advanced monitoring technologies is often not considered sufficient to be used directly by EPAs, especially when it comes to regulation and enforcement. Environmental protection agencies can help by focusing on networks of these sensors to obtain a synoptic picture of environmental quality (see Volten et al. and Ceccaroni & Piera in this volume), supporting a system for evaluation or certification of sensor technologies, providing information on appropriate technologies and developing guidance on messaging and interpretation of data from advanced monitoring technologies (Hindin et al 2016).

## Communication with citizen science data providers

Encouraging the active participation of volunteer environmental observers in organised projects brings benefits for EPAs and for the individuals and communities involved but, not surprisingly, also generates expectations on government agencies. If agencies wish to empower and engage the public on environmental issues by providing them with the means to gather relevant data, good feedback on the value of the data is important to keep volunteers motivated (Geoghegan et al. 2016). This feedback may, for example, relate to data quality, consistency of protocols or the utility of the dataset for agency work. Significant resources are required to provide effective and continuing feedback on any citizen science initiative. Environmental protection agencies can set up systems to provide this information to providers through appropriate data portals and other dialogue mechanisms.

Timely feedback on the usefulness of the data in effecting environmental improvement is also needed. Many engaged participants want to know if their efforts to measure or report on environmental issues have made a difference and contributed to positive change (Trumbull et al. 2000) or become more engaged in environmental issues. Timely feedback can be successful where there are direct and reasonably rapid results, as in the pollution alert system set up by the Irish EPA (see box 20.2). Where volunteer data has to be aggregated over time or across a large number of contributors, or where resulting interventions take

years to have a measurable effect, managing expectations of volunteers can be much more difficult. It is important that EPAs address this problem. For example, the Anglers' Monitoring Initiative in the UK, jointly organised with the Environment Agency, reports back regularly on the outcomes of volunteer ecological quality assessments (including some successful prosecutions) to maintain motivation and participation (The Riverfly Partnership 2017).

## Integrating citizen science into the work of the agency

Many EPAs have begun citizen science work and are engaged in collecting data through volunteer participation. In a more limited set of examples, EPAs and other government agencies have responded to citizen science data collected by community groups or incorporated these data into EPA work (box 20.3; NACEPT 2016). The impact of citizen science can be increased when EPAs look to fill their data needs through citizen science projects initiated and conducted both in and outside of government. Boxes 20.1 to 20.4 illustrate the breadth of EPA engagement with citizen science through initiating projects (boxes 20.1, 20.2 and 20.4) and by responding to community-initiated data (box 20.3).

### Box 20.1. From opportunism to a strategic approach: Scottish Environment Protection Agency (SEPA)

The Scottish Environment Protection Agency, and its predecessors, has worked with members of the public to monitor the environment since before the term 'citizen science' came into widespread use. For example, 130 volunteer 'Rainfall Observers' have been providing daily records of rainfall from locations throughout Scotland for up to 40 years. These records support weather and flood forecasting, improve models to predict climate change and support the management of water resources (Scottish Environment Protection Agency 2017a). More recently, SEPA and partners have helped initiate a growing number of citizen science projects, including Plant Tracker (Plant Tracker 2017), River Obstacles (River Obstacles 2017), and Anglers Riverfly Monitoring Initiative (The Riverfly Partnership 2017).

SEPA has recently recognised the need for a more strategic approach to citizen science, partly in response to the challenges of sustaining an increasing number of projects. This strategic approach has comprised:

- A high-level strategy, signed-off by SEPA senior management, outlining when and how citizen science would help deliver core responsibilities and objectives.
- Published guidance on the types of citizen science the agency would support.
- Co-ordination of citizen science activities to ensure alignment with the overall strategy.
- Provision of relevant infrastructure support such as IT capacity and training.
- Development of a web-based portal (Scottish Environment Protection Agency 2017) to provide access to tools and resources, data input and feedback mechanisms.

To support this, SEPA commissioned 'Choosing and Using Citizen Science' (Pocock et al. 2017). This 'Blue Guide' offers a step-by-step approach to assessing whether the use of a citizen science approach is appropriate, through project design, initiation and promotion, to project reporting and evaluation (see figure 20.1).

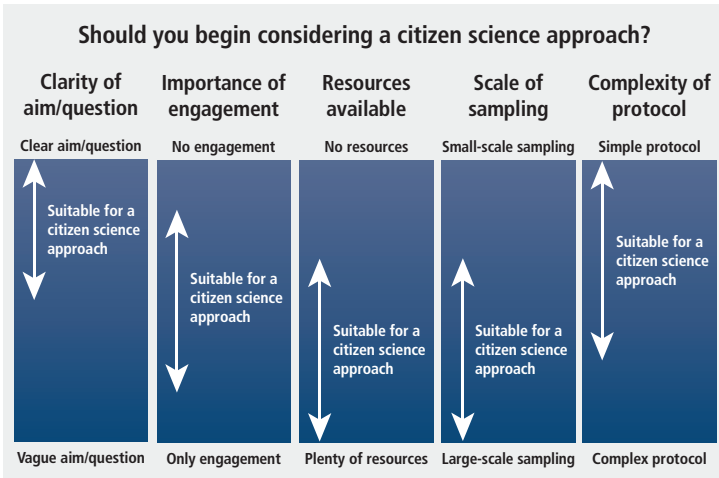


**Fig. 20.1** Key design elements for citizen science projects

Through the EU LIFE–funded 'Scotland's Environment Web', SEPA has also partnered on the development of a mobile app and web-based infrastructure to support citizen science projects. Examples include the 'Learn About Air' citizen science teaching pack for schools (Scottish Environment Protection Agency 2017b) and Scotland's Environment Citizen Science Portal for data entry (Scottish Environment Protection Agency 2017c).

SEPA's involvement in citizen science has taken a contributory approach until recently. It still needs to address building capacity (see also Richter et al. in this volume) in 'co-production' projects involving volunteers in project management, balancing open communication with SEPA policies, improving evaluation and maintaining participant motivation in the context of continuing constraints on public resources.

### Box 20.2. Improving the effectiveness of sentinel systems: Irish Environmental Protection Agency

The advent of smartphones has provided opportunities to engage the public in innovative ways that include the use of people as a network of sentinels of environmental problems. The Irish EPA developed a smart phone application called See it? Say it! to help people to report pollution in their towns and villages, including the illegal dumping of waste (Irish Environmental Protection Agency 2017). Users can take a photograph of the incident and add a description and contact details (see example photographs in figure 20.2). The app adds GPS location coordinates and the report is automatically sent to the relevant enforcement agencies or local authority. This complements a 24-hour complaints phone line. Reports are also delivered to FixYourStreet.ie which all Irish Councils monitor.

The uptake of the application has been good; 29 per cent of all environmental complaints on Fix Your Street now arrive via See it? Say it! and 1,500 complaints were received in 2015 when the app was launched. Figure 20.3 provides a snapshot of reported incidents throughout Ireland on specific days in 2015.

**Fig. 20.2** Examples of postings received from all over Ireland in July 2016. (Photos: Elena Bradiaková)

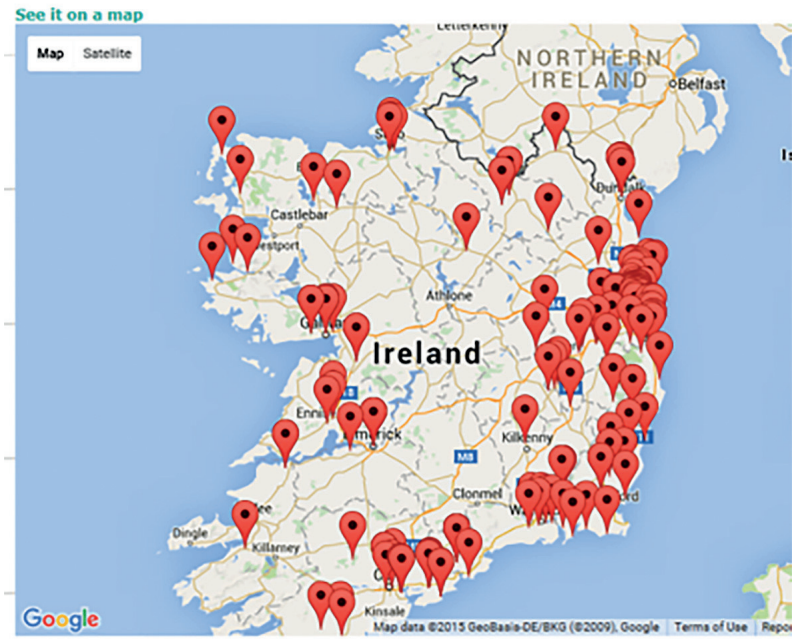


**Fig. 20.3** Distribution of reported pollution incidents, summer 2015

*(continued)*

This method of reporting has proved useful to regulators and local authorities given its locational accuracy and the detail provided by photographic evidence. The main types of incidents reported include the dumping of waste, backyard burning, noise from commercial sites and pollution incidents such as fish kills. At the same time, public interest and engagement on local environmental issues is increasing, so careful resource planning is needed to meet demand.

### Box 20.3. Regulatory action spurred by citizen science: The Clean Air Coalition of Western New York and Tonawanda Coke Corporation

The residents of Tonawanda, New York, became concerned about chronic illness in the local community and the odours and smoke from 53 industrial plants nearby. Residents formed a 'bucket brigade', or community group that uses a low-cost canister to independently conduct air quality testing. The group tested for Volatile Organic Compounds (VOCs) using grab samples collected in buckets purchased at a hardware store. Initial sampling showed extremely high levels of benzene and high levels of formaldehyde. The Coalition approached the New York Department of Environmental Conservation and the US EPA with the data collected, who then conducted a comprehensive, year-long air quality study including four permanent air monitors. This study confirmed that benzene levels were 75 times higher than the EPA guideline, and that there were high levels of five additional air pollutants, and identified Tonawanda Coke Corporation as the predominant source. As a result, Tonawanda Coke Corporation installed new air controls, resulting in a 92 per cent decrease in benzene emissions. A representative from the US Department of Justice became aware of the issue, which resulted in an individual conviction against the Tonawanda Coke environmental manager for misleading information about chemical emissions (James-Creedon 2016).

### Box 20.4. The Enviróza school programme

Enviróza is a citizen science game for primary and secondary schools, created by the Slovak Environment Agency. It was financed by the EU Cohesion Fund as part of the Operational Programme Environment (2007–2013) and launched at the start of the 2013/2014 school year, under the auspices of the Ministry of Environment of the Slovak Republic.

Using Enviróza, participants (teachers and pupils) seek out and identify contaminated sites, publish their data online and score points for doing so. Through accompanying competitions, they also inform the public about this issue, contributing not only to environmental conservation but possibly also to participants' health.

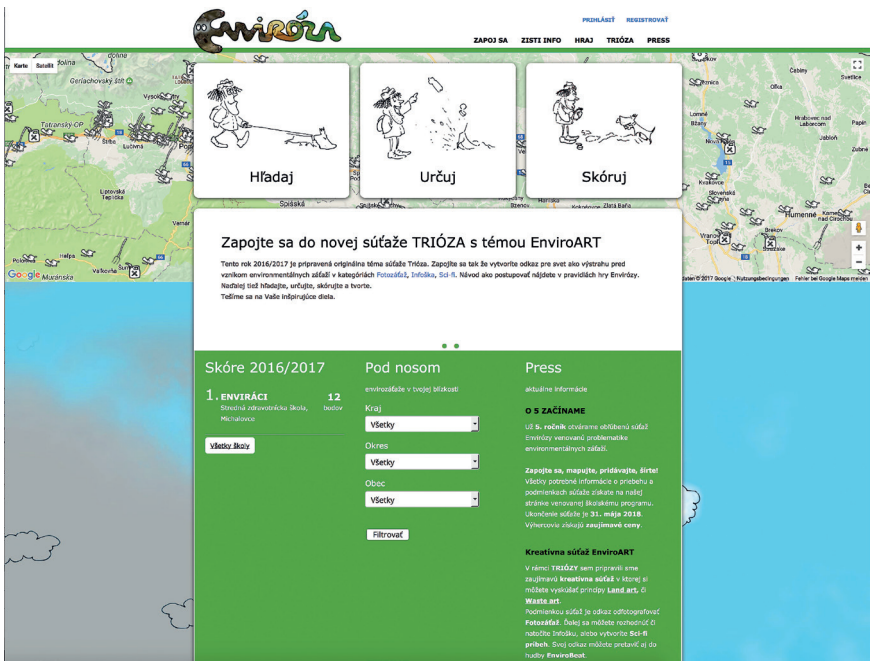


**Fig. 20.4** Homepage of the school programme Enviróza website. (Source: http://www.enviroza.sk/)

*(continued)*

**Fig. 20.5** A total of 25 new contamination/contaminated sites were added by schools. Field inspection and evaluation was then carried out by a SEA expert to allow their classification in the ISCS. (Photo: Irish Environment Protection Agency)

Enviróza is intended to update information about selected contaminated sites registered in the Information System of Contaminated Sites (ISCS) and to identify new sites (known as school-identified sites) that display signs of serious contamination. Data gathered by participants is processed by the Slovak Environment Agency (SEA), integrated into the ISCS and thus made available to state authorities as well as professionals and the public.

Enviróza's educational goal is for participants to gain information about existing contaminated sites and the state of their environment based on first-hand observations in the field. In the process, pupils develop skills with maps and navigational tools; work with data and use ICT; and gain experience working as a team as well as thinking critically and expressing their opinions. The programme provides teachers with an experiential learning tool for environmental education and incorporating the issue of contaminated sites into other school subjects, including mathematics, information technology, biology, chemistry, art and civics.

## Conclusion

Environmental protection agencies can support and encourage citizen science by providing access to innovative mobile sensors and applications; data capture infrastructure and communication; advice on funding; and demonstrating the practical uses of evidence generated through citizen science. Most importantly, EPAs can support citizen science by validating its use and integrating it into agency work. Investment in a few key areas can support the contribution that citizen science makes to environmental protection (Blaney et al. 2016; NACEPT 2016). Small investments can support big progress, for example, building in feedback mechanisms between projects and agencies; supporting data management and standards; and creating technology standards and support.

Recent advice and recommendations directed at EPAs and citizen science projects have provided guidance to support this transformative approach through key contributions. In December 2016, the National Advisory Council for Environmental Policy and Technology recommended that the US EPA invest in citizen science, improve technology and tools, enable the use of citizen science data, and adopt a positive, co-operative agenda that increases the use of citizen science data. The Council also recommended that the US EPA provide guidance and communicate data quality needs for different data uses. The UK Environmental Observation Framework provided recommendations including that citizen science activities be rigorously evaluated and that research should be encouraged on the 'difficult-to-quantify' benefits of citizen science (Blaney et al. 2016).

Citizen science projects and participants can also work to maximise the value of their efforts for environmental protection. Citizen science groups can (1) engage early with EPA staff to increase the relevance of citizen science project objectives and outcomes for the responsible agencies, set expectations and guide projects for maximum impact; (2) ensure project planning includes careful communication and feedback loops to ensure equitable collaboration, motivation and learning; and (3) seek to co-design projects with staff at EPAs and other organisations to ensure that the intended use, accessibility, quality and constraints of the data are factored into project planning and implementation.

Citizen science can have a significant impact in achieving environmental protection by generating new knowledge, raising awareness and empowering community members. Over the next decade, EPAs will continue to turn to citizen science to work towards environmental protection

in collaboration with the public, and additional case studies will support the potential uses of this powerful approach. Citizen science will enhance science and open opportunities for EPAs, community groups and other organisations towards the shared goal of environmental improvement.

## Acknowledgements

Box 20.1 was provided by Dr. Paul Griffiths, Environmental Quality State of Environment Unit, Scottish Environment Protection Agency. Box 20.4 was provided by Elena Bradiaková, Contaminated Sites Expert, Slovak Environment Agency. This chapter was supported in part by an appointment to the Internship/Research Participation Program at the US Environmental Protection Agency (EPA), administered by the Oak Ridge Institute for Science and Education through an interagency agreement between the US Department of Energy and the EPA.