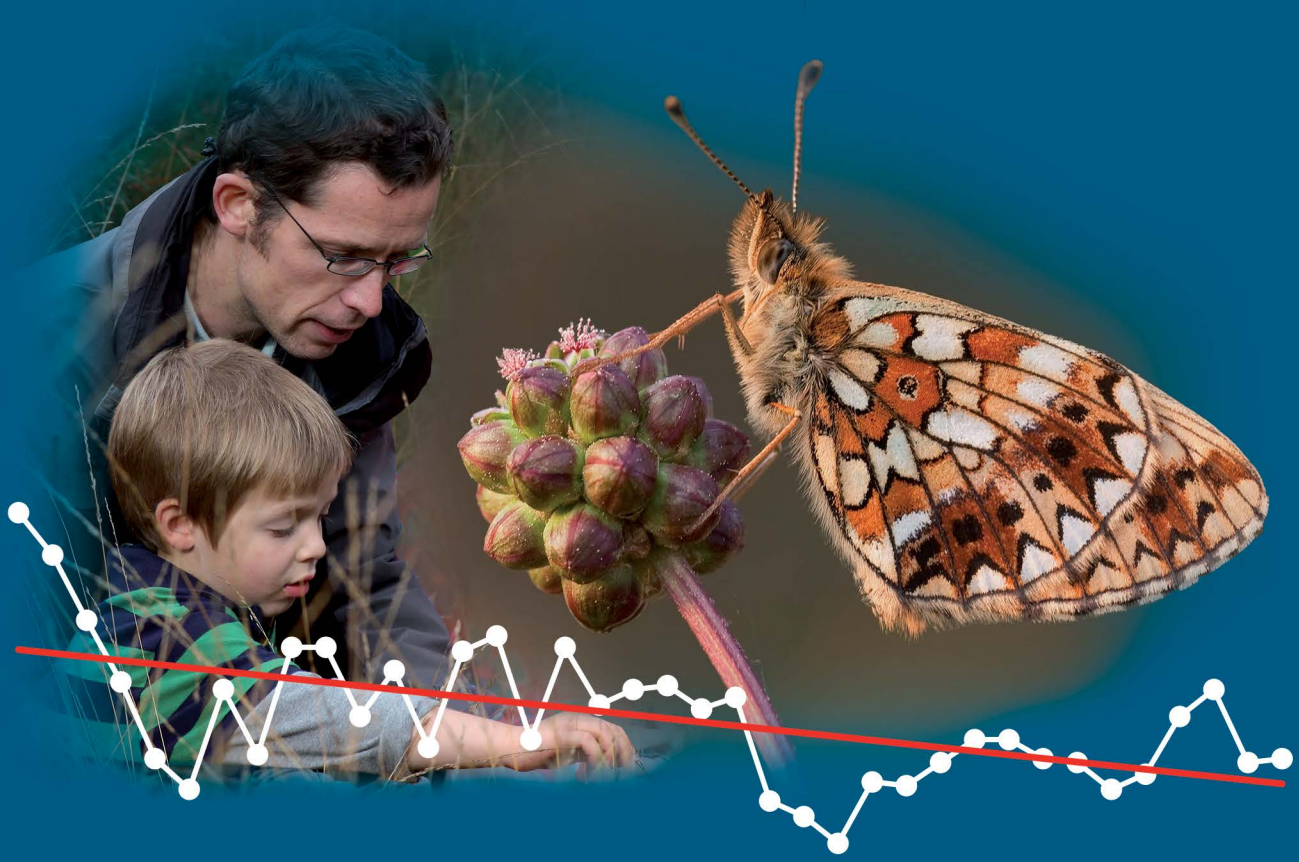
Choosing and Using Citizen Science

a guide to when and how to use citizen science to monitor biodiversity and the environment



SEPA
Scottish Environment Protection Agency

CEH
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Acknowledgements

We would like to thank the Scottish Environment Protection Agency (SEPA) for funding this guide and Claire Campbell at SEPA for her enthusiasm and guidance. We thank the Centre for Ecology & Hydrology for providing support during the guide's production and to Heather Lowther and Amanda Hill for their superb contribution to its design. Finally thank you to the volunteers and citizen science enthusiasts who have inspired this guide.

Citation

Pocock, M.J.O., Chapman, D.S., Sheppard, L.J. & Roy, H.E. (2014). **Choosing and Using Citizen Science: a guide to when and how to use citizen science to monitor biodiversity and the environment**. Centre for Ecology & Hydrology.

ISBN: 978-1-906698-50-8

This guide is a shortened and adapted version of: Pocock, M.J.O., Chapman, D.S., Sheppard, L.J. & Roy, H.E (2014). A Strategic Framework to Support the Implementation of Citizen Science for Environmental Monitoring. Final report to SEPA. Centre for Ecology & Hydrology, Wallingford, Oxfordshire.

Michael J O Pocock[1], Daniel S Chapman[2], Lucy J Sheppard[2], and Helen E Roy[1]

[1] Biological Records Centre, Centre for Ecology & Hydrology, Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB

[2] Centre for Ecology & Hydrology, Bush Estate, Penicuik, Midlothian, EH26 0QB

Front cover photographs: l to r - Susie Pocock; CEH; Shutterstock.

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

The Centre for Ecology & Hydrology (CEH) is a world-class research organisation focussing on land and freshwater ecosystems and their interaction with the atmosphere. We are a Natural Environment Research Council (NERC) Research Centre with 425 researchers and students based at sites in England, Scotland and Wales. CEH tackles complex environmental challenges to deliver practicable solutions so that future generations can benefit from a rich and healthy environment. www.ceh.ac.uk

BRC Biological Records Centre

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

About this guide

Citizen science can be a very useful 'tool' for undertaking research and monitoring, while also engaging with many people. Citizen science is very diverse; there are many different ways for volunteers to get involved with real science. This diversity can be overwhelming for someone seeking to organize a citizen science activity and citizen science will not always be the most appropriate or optimal approach for undertaking scientific research or monitoring.

Here we aim to provide guidance to support people considering using a citizen science approach, especially (but not necessarily restricted to) monitoring biodiversity and the environment in the UK. It will help you decide whether citizen science is likely to be useful, and it will help you decide which broad approach to citizen science is most suitable for your question or activity.

This guide does not cover the practical detail of developing a citizen science project. That information is provided in the 'Guide to Citizen Science' (Tweddle *et al.*, 2012).

Contents

1 Introduction to citizen science

What is citizen science?

Citizen science is an increasingly popular approach to undertaking monitoring and scientific research. Citizen science is defined as the involvement of volunteers (i.e. people who are not involved as part of their employment) in science, so it has the dual benefits of making a contribution to 'real' science, while also engaging many people with science. Often, citizen science projects are set up by 'professional' scientists. Volunteers then contribute data to the project. Such an approach is referred to as 'contributory citizen science' and this is currently very widely-adopted. However, there are many different types of citizen science (Roy *et al.* 2012) including projects strongly shaped by the volunteer participants, so-called 'collaborative' and 'co-created projects' (Bonney *et al.* 2009). For projects involving environmental monitoring in which there is a clear end-use for the data, the contributory model of citizen science is usually most relevant.

The aim of this guide

In this guide we provide a decision framework to help guide people who are considering whether a citizen science approach can contribute to their work. This guide should help you to discover:

1. whether citizen science is suitable for your proposed project, and;
2. what type of citizen science is most appropriate for you to adopt.

We believe that the decision framework will help people to more clearly understand the potential opportunities and limitations of citizen science. This is necessary because there is such a wide range of citizen science approaches (Roy *et al.* 2012) and not every approach is suitable for all situations. Therefore, for someone with a question to answer, or a monitoring need to be met, it can be daunting to consider whether citizen science can be used and, if so, which citizen science approach is best. In this report we do not repeat the 'Guide to Citizen Science' (Tweddle *et al.* 2012) which was written specifically to assist in developing and implementing environmental and biodiversity citizen science, or the Citizen Science Toolkit (Cornell Lab of Ornithology 2013). We recommend that interested people consider the decision framework in this guide, and if they conclude that citizen science is relevant and worthwhile, they should then refer to the advice in the 'Guide to Citizen Science'.

Photo: Lesley Deans, Clyde River Foundation

Why is citizen science so popular?

There are many reasons why citizen science has become so popular in recent years:

1. **Excellent engagement.** Citizen science provides a way for people to engage with science and their environment. Although people's motivation for taking part in citizen science varies considerably, participants often describe it as fun and providing a way to contribute to something important and valuable.

Photo: Heather Lowther, CEH

2. **Cost-effective data collection.** Citizen science provides the potential to collect data at much larger spatial and temporal extents and much finer resolutions than would otherwise be possible. Even if the data could be collected through other means, citizen science can be a cost-effective way of collecting the data while also providing an excellent opportunity for people to become engaged with a subject.
3. **Technological advances make promotion and data collection straightforward.** Over the past decade, advances in technology, especially in communications technology, have made it easy to set-up and promote citizen science projects. Data collection, via websites or smartphones, is now a standard approach and relatively inexpensive to implement. Feedback to participants can be provided quickly and easily.
4. **The data can be trusted.** Increasingly the important step of data validation is taken in citizen science projects in order to provide data of known quality, for example, verifying every record, or quantifying the accuracy of a sample of the data so that error can be taken into account in analyses. Both approaches provide trustworthy data; analyses of citizen science data are published in the scientific literature and used in national biodiversity indicators.
5. **Volunteer involvement in science has a long history.** With the increased use of the term 'citizen science', volunteer-led environmental monitoring that has been going on for decades is now often described as 'citizen science'. We can learn from the successes of past activities in developing current projects.
6. **Diversity of approaches.** Different types of citizen science appeal to different people, e.g. expert volunteers, interested community stakeholders or members of the general public. 'Mass participation' approaches are popular, but so are approaches to engage with expert naturalists.

Citizen science and its role in long-term monitoring

Monitoring the environment has a long history of benefiting from volunteer involvement through citizen science. The reason for this is that the volunteers involved can be very committed and are distributed around the country, so permitting the long-term collection of data in widely-distributed locations. Expert volunteer naturalists can have considerable expertise in identifying species (in many cases more than the 'professional' scientists). If resources are available to support the volunteers then large-scale monitoring projects can run for decades (e.g. the UK's Breeding Bird Survey and the UK Butterfly Monitoring Scheme).

It can be tempting to think that citizen science is a cheap (or even free) way of fulfilling all large-scale monitoring needs because citizen science data are free at the point-of-collection. This is not the case. Investment needs to be made to support volunteers. The annual support for citizen science projects providing data for UK headline indicators is about £100K per project per year (Roy *et al*. 2012), although many citizen science projects require much less budget than this. However, despite its cost, citizen science may be a very cost-effective way of undertaking monitoring.

It is misleading to think that citizen science has to replace professional surveillance; the two are not mutually exclusive. Citizen science could be effective when adding to and complementing professionally-collected data. For example, core professional activity could provide the minimum level of monitoring required, while citizen science data increases the resolution and accuracy of sampling. Citizen science data could also inform professionals so they direct their effort to address the highest priorities or most important questions.

Some long-term monitoring is unsuitable for citizen science because it is not possible to collect the data safely or accurately without specialist equipment.

Photo: SEPA

2 Advantages and disadvantages of a citizen science approach

Advantages of a citizen science approach

- It can be a cost-effective way of gathering data, especially at large spatial and temporal extent and fine and spatial temporal resolution. That is, the balance between the long-term cost of acquiring suitable data 'professionally' is more than the cost of supporting volunteers to acquire these data.
- For long-term monitoring, committed volunteers can provide a reliable way of gathering data, less subject to the vagaries of the availability of funding than professional monitoring.
- By getting people to be hands-on with data, it directly engages people with environmental issues and their local environment.
- Citizen science can provide high-quality data. Data from citizen science projects can vary in quality, but if it is collected appropriately and subject to quality assurance, then the data can be eminently suitable for regulatory purposes. For example, 7 of the 26 UK headline indicators are reliant on volunteer-collected data (Defra 2012) and monitoring of watercourses in the USA is undertaken by volunteers according to Environmental Protection Agency protocols to meet regulatory requirements (Nerbonne & Nelson 2004).
- In some cases the expert volunteers have superior skills to the 'professionals', particularly with respect to natural history and the identification of species.
- Many volunteers are willing to follow protocols (even quite complex ones) in order to collect data in a standardised way, when they are confident that their input is valuable.
- Citizen science can permit the detection of rare events across large spatial and temporal extents, which would otherwise be difficult to survey for.
- It need not be restricted to what people can see; people can use sensors, or they can collect samples for analysis by volunteers or by professionals.
- "Crowd sourcing" enables people to undertake small or simple tasks via a computer (e.g. classifying images) which can contribute to analysis of large datasets and would not otherwise be achievable by a small team or using automated processes.
- Citizen science is enjoyable and it can enhance the well-being of volunteers.

Disadvantages of a citizen science approach

- Citizen science is often most effective when the approach is simple. Participation is likely to be reduced when protocols are too complex or demanding or recording needs to be repeated over time or in different localities.
- Volunteers need to be recruited. Some citizen science projects use straightforward protocols which can be rapidly completed by anyone in any location. Such an approach aids mass participation. However, complex and structured protocols can be suitable for citizen science especially if they appeal to a particular group of enthusiasts such as anglers, ramblers, naturalists, school children or others.
- Citizen science often requires substantial investment in resources. Citizen science data are free (to you) at the point-of-collection, but they are (often) not cheap. A considerable investment in money, resources and time is usually needed to support citizen science.

Advantage and disadvantages - continued

However, citizen science can be run entirely through the commitment of a volunteer organizer, e.g. the volunteer-led biological recording schemes in the UK. Resources are required to:

- Provide feedback to volunteers, and this should continue throughout the life of the project in order to provide motivation for participants.
- Provide support for the means of collecting data (e.g. online databases and web interfaces, or smartphone apps).
- Validate data to ensure that they are trustworthy and appropriate for their intended use.
- Recruit, support and retain volunteers (e.g. through training, mentoring, providing feedback, keeping supporting materials and websites up-to-date and working etc.).

- Investment in the project (in terms of time and money) needs to continue through the life of the project in order to support and retain individual volunteers.
- There can be tensions between the motivations of participants and organizers (Rotman *et al.* 2012) - what you think is important may not interest an 'ordinary' person! People take part because they are motivated through interest, curiosity, concern or to have fun. Participants may expect to see rapid local action arising from their involvement, but this may not be an intended outcome of the project. The aims of the project need to be clearly explained to manage the expectations of the participants.
- Citizen science data (especially from mass participation projects) are often 'unstructured' (i.e. the times and locations of samples are not subject to statistical design). It can require complex approaches to analyse the data and the data may not even be suitable for purpose for which it was intended. Therefore more data might be needed to provide adequate information than would be necessary with professional, systematic monitoring.
- Data acquisition becomes outside of your direct control. That is, citizen science is most suitable where data cannot be collected any other way (i.e. you are not diverting resources from currently adequate monitoring), or where the data will be useful but not essential.

Photo: Lesley Deans, Clyde River Foundation

3 A decision framework for choosing and using citizen science

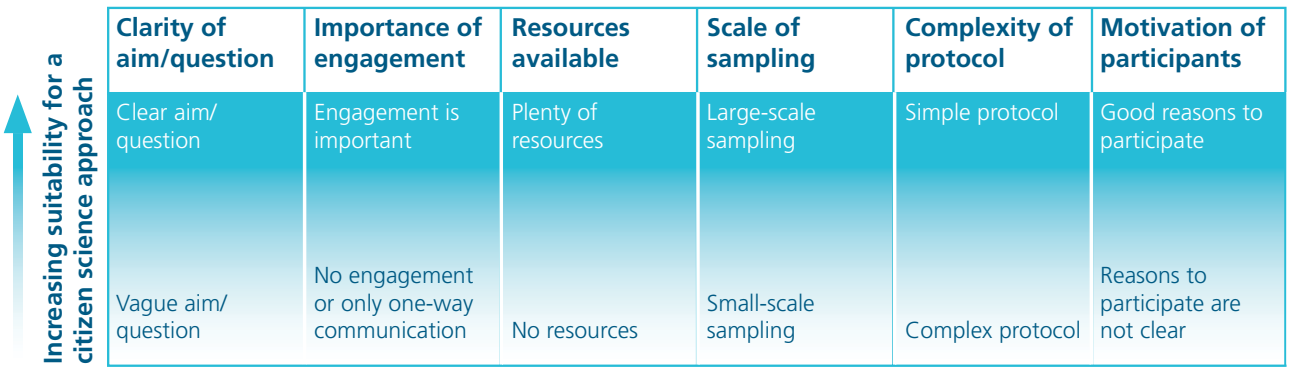
In this part of the guide we present a decision framework, to assist in the selection of a citizen science approach. We also include some preliminary questions and subsequent thoughts to help advise on the suitability of citizen science.

Precursor to the decision framework: before you even consider citizen science

We recommend that before you seriously consider citizen science, you review six aspects: the clarity of your question or aim, the importance of engagement, the resources available, the spatio-temporal scale of sampling, the complexity of the protocol and the motivations of participants. The suitability of a citizen science approach is summarised in Figure 1, and expanded in the remainder of this section. It is also worth thinking about the types of information which you could collect.

Figure 1: Six broad areas to review, prior to using the decision framework, to assess the suitability of citizen science to your circumstance.

Should you consider a citizen science approach?



Before you choose citizen science

The clarity of the aim or question

Citizen science is just like any scientific approach: it is at its best when it is specific, i.e. when the question being addressed is precise. For citizen science data to be fit-for-purpose, the purpose needs to be clearly defined.

For many projects, e.g. where citizen science contributes to primary scientific research, the aim is well-defined. It can be phrased as a testable hypothesis, leading to very effective citizen science (Silvertown 2009). However, citizen science can also contribute to environmental surveillance and monitoring. Where citizen science contributes to monitoring the effect of an environmental pressure (e.g. diffuse pollution), it is important for there to be a well-understood cause-and-effect pathway from the pressure to what is being recorded.

Key question: Do you have a precise and clearly-defined aim for your citizen science project?

The importance of engagement

Engagement is an important component of citizen science but engagement on its own is not citizen science. Perhaps you have an important message to convey but with no need to gather data. There are many excellent examples of communication to raise awareness of a particular issue.

However, perhaps you have an idea for engagement which could be extended to involve people in gathering useful data, in which case it becomes citizen science. Citizen science can enhance engagement – the citizen science acts as a highly participatory way for people to engage. So if you are considering undertaking an engagement activity think whether you can get more from the initiative by encouraging people to contribute through citizen science (i.e. asking a genuinely interesting scientific question, or gathering data for a genuinely useful scientific need).

But there may be no need for people to gather data and the purpose of the project is to increase awareness around a particular issue. This could be extremely important in its own right; in which case keep it simple and invest in excellent engagement rather than trying to make it a citizen science project.

Key question: Can you extend your engagement activity into meaningful and relevant citizen science or should you simply undertake excellent engagement for its own sake?

Photo: Michael Pocock, CEH

Before you choose citizen science - continued

The resources available

It is important to consider what resources will be required to run your initiative effectively. Will you need a website? Will you need an online database? And, if so, can you use existing technology (e.g. Indicia, a database toolkit for biological observations; www.indicia.org.uk) to meet this need? Will you need to provide supporting resources such as guidance notes or specialist equipment?

If the resources (i.e. money and time) needed to adequately support the project are seemingly prohibitive then you could consider collaborating with other providers or using open-source software, which may make the costs more acceptable. The 'Guide to Citizen Science' (Tweddle *et al*. 2012) includes more detail about the sort of resources required for setting up and running a citizen science project.

Key questions: Do you have sufficient resources available to ensure you can support your volunteers for the entirety of the project? If not, can you collaborate and share resources which might also reduce duplication of effort?

The scale of sampling

Citizen science is particularly effective at addressing questions that require a large-scale approach, especially across large spatial scales (by engaging many volunteers simultaneously) because it is so costly to obtain these data any other way. It is also useful when considering a very long-term approach, in which volunteers remain committed through peaks and troughs of funding cycles (although long-term citizen science does require long-term commitment from the organiser).

Citizen science could potentially work extremely well for both extensive large-scale and intensive small-scale studies. However, where there is a need for data across a large spatial scale it is important to consider whether you need information from particular sites or whether an ad hoc approach will suffice. Are some of the places where you would like observations particularly remote? If so, can you get people to travel to these sites of interest?

Key question: Do you need lots of people (or volunteer time or commitment) to achieve your aims?

Photo: Heather Lowther, CEH

Before you choose citizen science - continued

The complexity of the protocol

Perception of citizen science is skewed by so-called "mass participation" citizen science projects which are promoted through the mass media and typically involve many people in gathering simple data (e.g. a wildlife observation or a single measurement). Simplicity is one key to the success of mass participation citizen science projects. As the complexity of the protocol increases then the number of participants is likely to decrease, even though the value of the data may increase (e.g. because the dataset is more detailed). If you require the use of a complex protocol then ensure you provide sufficient support for participants and you thoroughly test the protocol (Tweddle *et al*. 2012).

Never presume too much of a volunteer; their time is given freely and they are not obliged to provide data. Ensure that you consider the motivation of your participants and maximise their enjoyment and satisfaction in taking part. This includes supporting their understanding of the importance of their record, and so requires you to provide feedback to participants. Feedback should ideally be both immediate (e.g. a 'thank you' for the record which could be automated or personal) and more considered (e.g. an end-of-year report for volunteers).

Key question: Is your protocol practical for volunteer involvement? Are you expecting too much from the volunteers?

The motivations of participants

People will get involved and continue to stay involved for many different reasons; these reasons will vary between people and can change over time. It is important to consider people's motivations. Progression in a project can be important for them to remain motivated.

In terms of initial involvement, different projects will resonate with people in many different ways. Successful projects may resonate because of:

- a sense of place ("it is my river"),
- a sense of community ("I can take part with my children"),
- a pre-existing interest ("I've always liked butterflies"),
- a sense of discovery ("I had no idea that…"),
- being part of a narrative ("I'm taking part with others …"),
- or a sense of jeopardy ("my trees are under threat").

This does not mean that the focus of your proposed study has to already have popular appeal, because even unlikely subjects can be communicated in such a way that they resonate with people.

People also need a 'trigger' or prompt to make a record. Ideally triggers that will prompt involvement should not be too common (otherwise people feel overwhelmed and disengaged) or too rare (otherwise people will forget to participate), unless the event is rare and spectacular (e.g. a dead swan or a landslide). Often subtle changes to a question can make the trigger clearer and the data more useful. For example, asking people to report the health of garden birds may be too general, while asking people to report sick birds in their garden or to report the health of garden birds on a particular day may be more successful.

Remember that the importance you place on an issue is not relevant – it is how strongly it resonates with potential volunteers that will determine how motivated they are to take part.

Key question: Does your project resonate with potential volunteers, and are there clear and appropriate triggers for people to make records?

Examples of using citizen science

Example A

Anglers' Riverfly Monitoring Initiative. The Riverfly Partnership is a network of nearly 100 organisations representing anglers, river managers, conservationists and relevant authorities.

The Partnership focuses on monitoring three groups of insects: caddisflies, mayflies and stoneflies which live most of their lives as larvae in fresh waters. Riverflies are a major link in the aquatic food chain and are considered to be important biological indicators of water quality. Indeed they have been described as "the canaries of our rivers".

In 2007 the Anglers' Riverfly Monitoring Initiative was launched by the Riverfly Partnership, recognising the important role that anglers play in detecting change in the river environment. The Anglers' Riverfly Monitoring Initiative provides a variety of resources (including survey protocols, identification guides and practical guidance on aspects such as health and safety).

Local projects, such as the Clyde Riverfly Monitoring Partnership (CRIMP) in Scotland, provide opportunities for interested volunteers (especially anglers) to be trained in a simple monitoring technique for riverflies. Trained volunteers then undertake regular monitoring at their sites. When severe perturbations in water quality are recorded they can pass information on to statutory bodies who can then take the necessary action.

There are several documented occurrences of successful action (e.g. prosecution of polluters). The Anglers' Riverfly Monitoring Initiative also links to other relevant activities, such as recording non-native crayfish, and disseminates relevant information, such as guidance on biosecurity and awareness of non-native species.

Monitoring through the Initiative provides valuable national information about water quality, but importantly it also directly benefits the local volunteers seeking to help protect their river or lake.

http://www.riverflies.org/

http://www.clyderiverfoundation.org/crimp/

Example B

The Conker Tree Science project (Pocock & Evans 2014) engaged over 8,000 people. It was hypothesis-led, so the aims of the project were very clear. The questions addressed the national-scale impact of a leaf-mining moth, so it would not have been possible to undertake this research without engaging people across Britain.

Through participating in the project people became engaged in making discoveries about insects, e.g. rearing tiny moths and parasitic insects.

The project received initial funding to set it up, but it continued for four years with a substantial investment of time from the project organisers. There were three main ways in which people could get involved which varied in their complexity (from making a record with a smartphone app to rearing insects from horse-chestnut leaves).

The project appeared to have strong resonance with people; horse-chestnut trees are very popular, and the damage caused by the moth was very visible. However, many people will frequently see horse-chestnut trees, so this may have created too many triggers, thus limiting participation.

www.conkertreescience.org.uk

Examples of using citizen science - continued

Example C

The Biological Records Centre at the Centre for Ecology & Hydrology has been supporting recording schemes and societies, thus contributing to long-term monitoring of biodiversity for 50 years.

The involvement of volunteers has provided a degree of stability through fluctuations in funding available to support them. The data have been used to describe changes in species distributions and abundances, particularly in response to environmental change, and contribute to scientific research and policy.

The recording schemes and societies are led by expert volunteers who have a passion for a particular group of animals or plants, and who commit vast amounts of time to supporting recorders and verifying records. Some groups are tricky to identify and so recorders require substantial expertise. For these groups the support and mentoring of new participants is invaluable. Other groups are easier to identify, e.g. ladybirds. The UK Ladybird Survey has successfully popularized the recording of this charismatic group of insects. Many of these data are submitted as and when recorders choose to make records, but the UK Butterfly Monitoring Scheme is a structured scheme in which volunteers who have expertise in recording butterflies make records weekly along a set transect. Their records contribute to the overall conservation effort for butterflies in the UK.

www.brc.ac.uk

Photo: Heather Lowther, CEH

Types of data

Many citizen science projects are based around people submitting records or observations with information about the place and time. However there are many other types of data that can be collected:

- Images, video or sound recordings which allow records to be verified or further analysed after submission.
- Measurements of something of interest which provides more quantitative data rather than presence/absence of something.
- Physical samples, e.g. water or biological samples, for the participant to analyse or to send off to be analysed professionally.
- Measurements from sensors can record things that people cannot directly observe (e.g. radiation) or cannot otherwise quantify (e.g. temperature or noise). Increasingly these measurements can be provided directly from smartphones or via plug-in sensors.
- Obtaining records from social media, e.g. 'harvesting' information from Twitter, Facebook or Flickr. This uses the information in the public domain, but does not engage people to collect it. (Many people would not class this as citizen science, but it may be useful nonetheless).
- Classifying data already collected. There are many tasks that are difficult to automate, but easy for humans for do, e.g. pattern recognition. If these can be divided into small tasks then the problem can be 'crowd sourced' and more people can be involved without needing to go outdoors. Crowd-sourcing like this is an increasingly popular citizen science approach.

Key question: Have you considered the different ways of gathering data using citizen science, including crowd-sourcing, collecting physical samples, citizen sensor networks, harvesting social media?

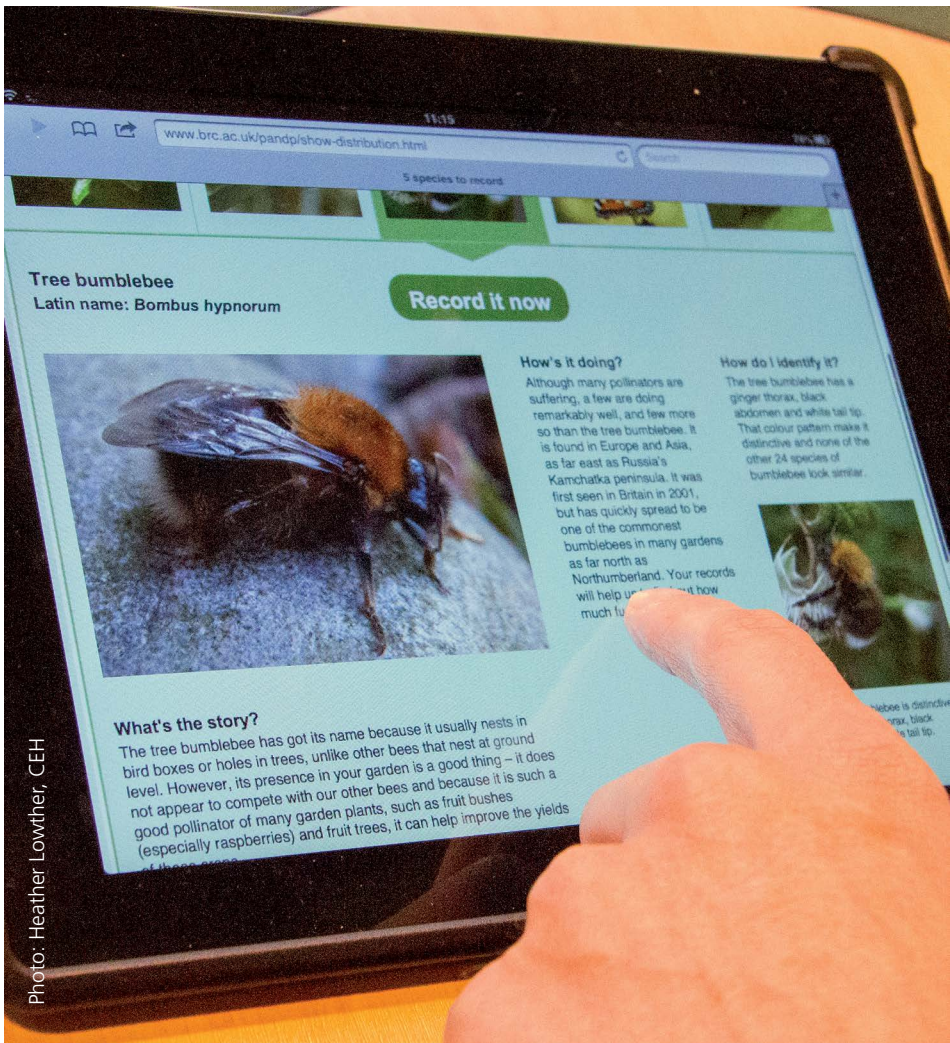


Photo: Heather Lowther, CEH

4 The decision framework
How to use the decision framework

We have created the following decision framework to provide guidance as to whether citizen science is suitable for you and, if suitable, which type of citizen science you should consider.

Using the decision framework with a clearly defined question

The decision framework is presented as a key. You can work through the decision framework question-by-question with a specific project goal/question which you have clearly defined in advance, in order to discover the suitability of citizen science for your proposed project.

Using the decision framework interactively

A second, more practical and more productive, use of the decision framework is when you are developing your question or goal and you use the decision framework question-by-question in order to refine and clarify your aim. We anticipate that by using the decision framework in this way, it will:

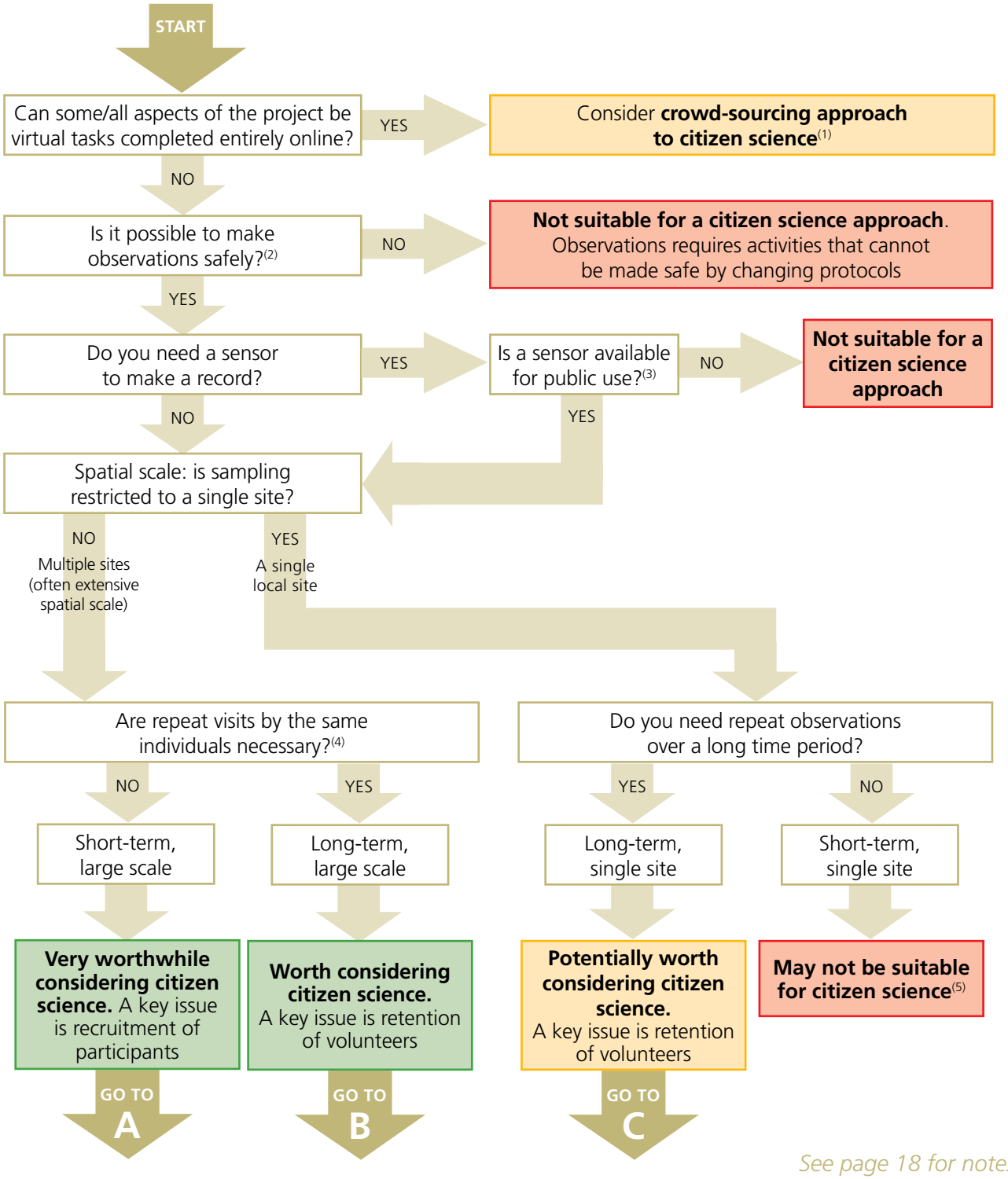
- Raise questions that you have not previously considered, thus broadening what you considered possible and so revealing the potential of a citizen science approach.
- Ask questions that you have not previously clarified, thus refining your overall question, so making it more precise.
- Allow you to see the likely impact of each decision on the suitability of citizen science for your proposed project.

We believe that the decision framework will be most productive when used in an interactive way, rather than a formulaic way.

Photo: Heather Lowther, CEH

The decision framework for citizen science

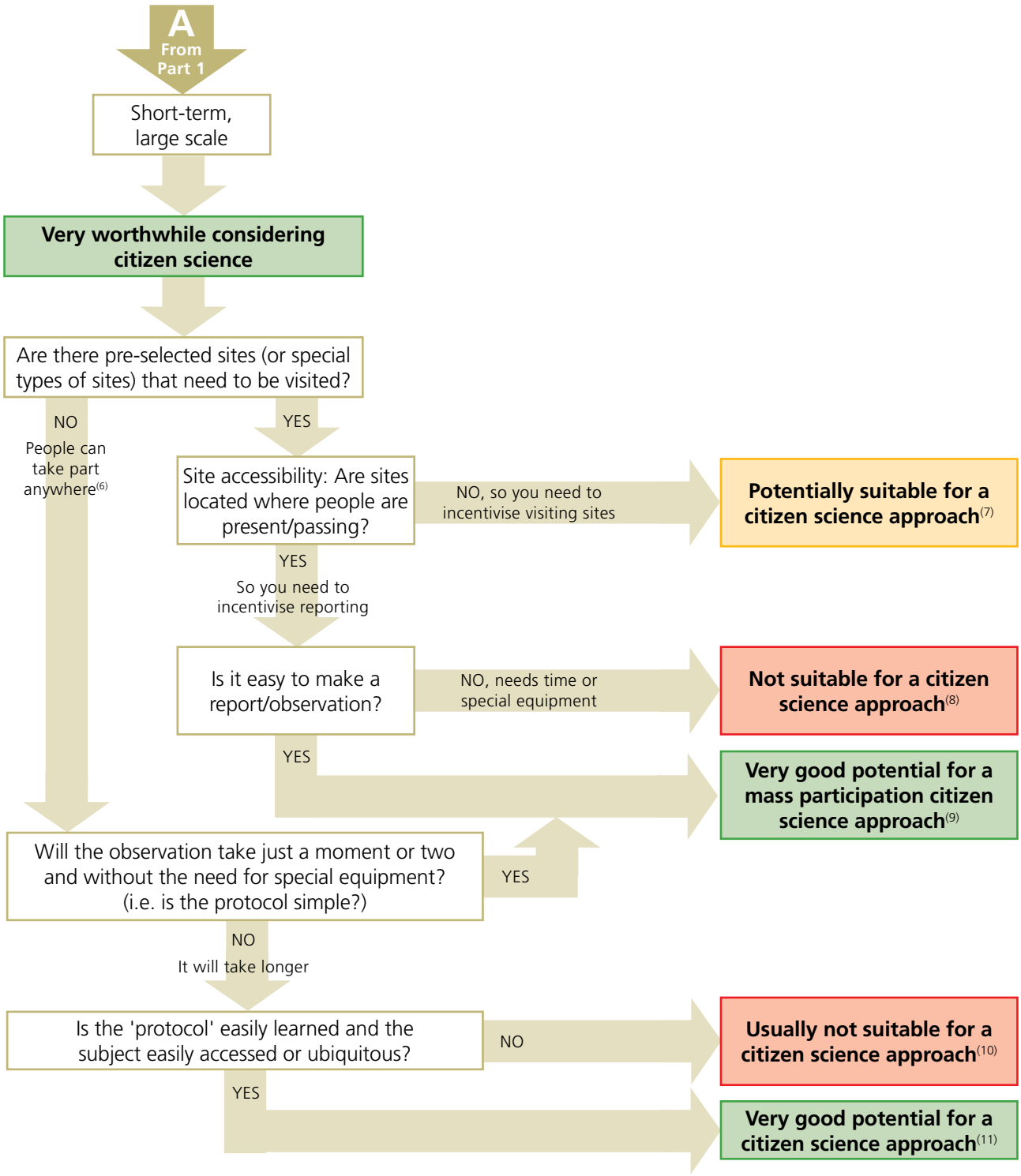
Part 1 of the decision framework



See page 18 for notes

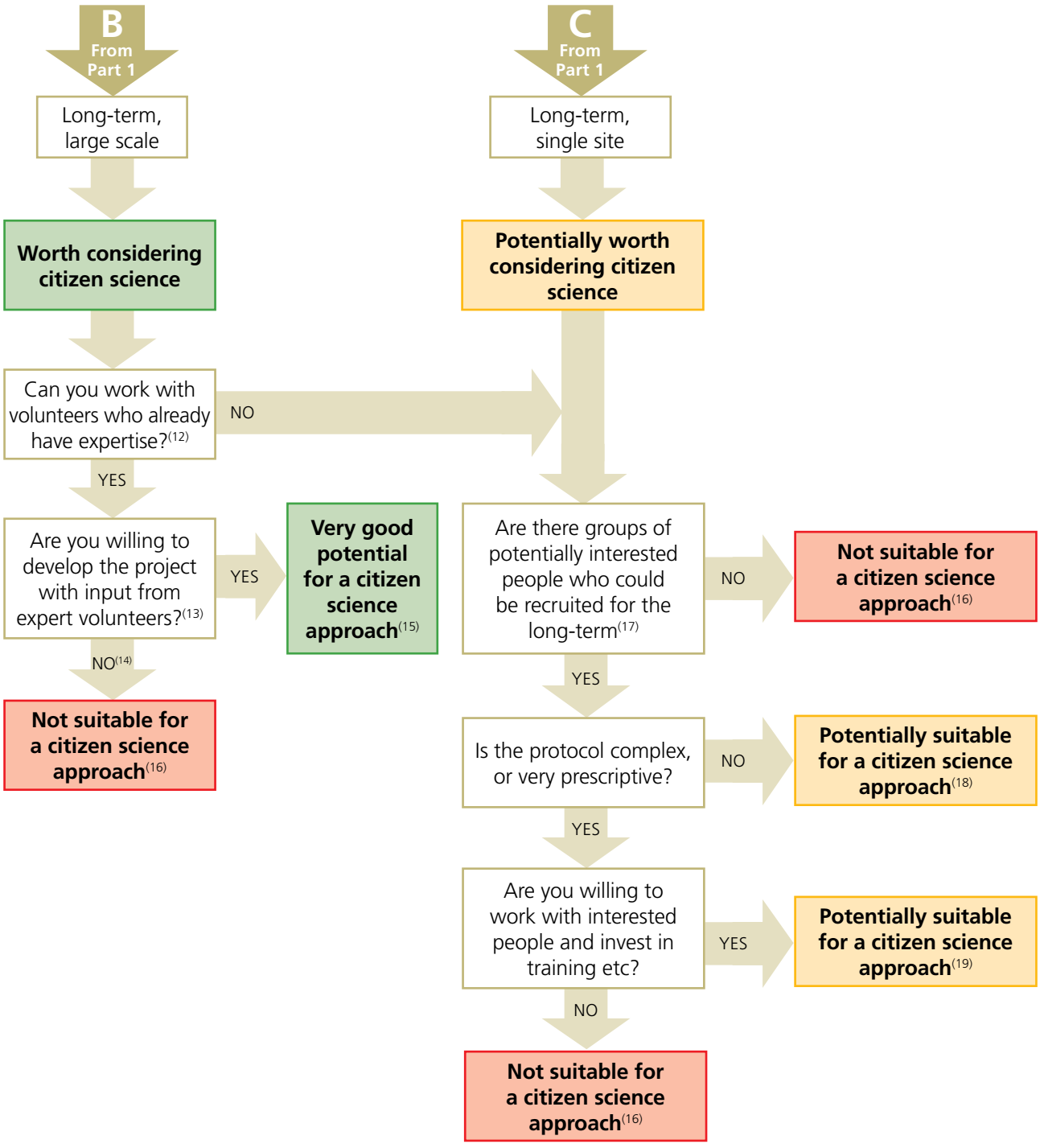
The decision framework for citizen science

Part 2 of the decision framework *(continued)*



The decision framework for citizen science

Part 2 of the decision framework *(continued)*



Notes on the decision framework

1. Here we use the term 'crowd-sourcing' to describe the sort of tasks that can easily be distributed for people to do on their own terms, especially at the computer. This is ideal for tasks that require human intelligence for problem solving or pattern recognition. Sometimes projects can be broken down to separate out-of-doors observations from a crowd-sourced (computer-based) component, thus permitting people to be engaged with the crowd-sourced components even when they are unable to make observations outside.

2. Safely does not mean risk free. Risk can be reduced with appropriate training but risk assessment is always needed for citizen science projects.

3. Limitations to a sensor being 'available' for public use include it being too complex or too expensive. However technological advances may quickly make sensor approaches affordable and tractable. Sensors could be made available by providing them free, or making them available to purchase (a form of 'crowd funding' of the project), hire or borrow.

4. We use the question about repeat visits rather than 'long-term', because monitoring can be long term but collected by multiple people (from the same site or from multiple sites). Our distinction here makes clear an emphasis on volunteer retention, not just recruitment.

5. Short-term, single-site projects can be ideal to engage with people and provide education, but are less suitable for citizen science. 'Bioblitzes' (recording as many species as possible on a site in one day) are short-term, single-site projects; their scientific value is due to the presence of experts, but they have an important role in public engagement with nature.

6. 'Anywhere' means people do not have to travel to somewhere specific to take part, though they may need to be in a suitable habitat. Clearly, there is a judgement to be made for each circumstance and each intended audience whether locations could be viewed as 'anywhere'. For example, depending on the audience 'large rivers' or 'arable fields' could be argued either way (most people are not near large rivers or spend time in arable farmland, but equally, a lot of people will visit large riversides, and many people could choose to visit arable farmland). Equally, a project requiring a visit to 'woodland' might require a special trip, but many people could choose to make that trip easily.

7. There are relatively few citizen science examples of trying to incentivise the visiting of sites (as is done with geo-caching), but there is potential for this.

8. Usually not suitable for citizen science due to a mismatch between the intended audience and the ease of reporting.

9. Mass participation projects can be ideal in gaining a 'snap-shot' overview of the state of something. Its success can rely on being featured in the mass media; alternatively it can take advantage of breaking stories in the news, in which case rapid response is necessary. You need to think clearly about the prompt for involvement (why would someone take part?), and whether sample sizes will be sufficient. Asking people to record something too infrequently is not ideal because they may forget the prompt to report it (unless it is very memorable). Asking people

Notes on the decision framework

to record something too frequently (e.g. all sightings of a common animal, or reports of river quality) is not ideal because there are too many prompts to record, hence it becomes too overwhelming and reduces motivation to submit reports. Making these observations more structured is an alternative (e.g. report your local river quality each month), but this comes under the sections regarding 'long-term' surveillance.

10. Usually not suitable for citizen science due to a mismatch between the intended audience e.g. the general public and the accessibility of the project.

11. Engaging with wide audiences to undertake something reasonably detailed is one of the classic examples of citizen science. Key questions for projects organisers is why people would get involved – what is the prompt to get involved now rather than later (and potentially forget to take part), and why people would take part a second time – what are the incentives for continued engagement? Such a project definitely needs sufficient (i.e. substantial) investment in supporting resources and in recruitment.

12. It can be more successful to work with people who already have expertise (and interest) in the subject, e.g. working with birdwatchers to undertake surveys, rather than trying to recruit people who do not already have an interest in birds.

13. This question is important because although there may be a regulatory desire to collect data in a certain way, if the intended volunteer participants are not amenable to that approach then pushing ahead with the project has a high chance of failure. However, by working with the intended participants you could work collaboratively to develop a project that is acceptable for the intended participants.

14. If you require long-term large-scale monitoring by volunteers but do not have a ready pool of willing expert volunteers then you need to think carefully about their incentive to be involved.

15. For this long-term surveillance, you need to demonstrate a long-term commitment to the project to fully engage with volunteers.

16. For this long-term surveillance, the issue of working in collaboration with your intended audience is really important (see [13]).

17. This question is about the audience that you have identified. Groups of potentially interested people are often people who have a vested interest in the outcome of the surveillance, e.g. local action groups, or anglers concerned about river quality, mountain walkers concerned about invasive plants etc.

18. A key question that you need to consider is why someone would start to get involved and why they would continue to be involved.

19. A key question here is whether you have the commitment to provide sufficient resources for long enough. Training participants requires time and investment. You could have quite high drop-out rates, but this approach has the potential to produce some really committed volunteers.

5 Final thoughts on choosing and using citizen science

If you have decided that citizen science may be useful, we strongly recommend that you refer to the 'Guide to Citizen Science' (Tweddle *et al*. 2012) to help you explore the steps in actually setting up a citizen science project. Here we summarise a few important aspects that you should consider, which are largely based on the 'Guide to Citizen Science'.

Resources: the organisers' time

Time is needed at all stages of projects: in the set up and design, in the running of the project, and in the reporting phase of the project. When setting up projects you will need sufficient lead time to test protocols, set up databases and websites etc. During the running of the project it is important to ensure that the websites continue to operate well (website links work, databases work, blogs are updated etc.). Project organisers need to be able to commit time for the duration of the project. If you are organizing the citizen science project, then your enthusiasm is vital to the success of the project. Within a large organisation this enthusiasm and commitment should be highly valued; there are many examples of citizen science projects that have been launched with great excitement but have rapidly ceased to be active or updated.

Photo: Michael Pocock, CEH

You will also need to provide resources for the analysis, interpretation and communication of results. Often the analysis of citizen science data is complex and while the analytical approach should be planned before the project is started, undertaking the analysis and communicating the results to participants and the general public (if appropriate) still requires resources.

Resources: infrastructure and data protection

Infrastructure is an important aspect of citizen science, particularly the use of online databases, visualisation

Final thoughts on choosing and using citizen science - continued

and feedback. Although web-developers can set up bespoke databases, there are many examples of mature technologies for databases and for visualisation (Roy *et al*. 2012). Broadly these can be divided into: 1) bespoke technologies that are designed for a specific purpose and audience; 2) adaptable template-type platforms where the project leader can modify the content within the bounds of the fixed parameters of the platform; and 3) technologies that have aspects of both. See the References and resources section for more information on these.

We strongly recommend that data are stored in a way that makes it easy to access and easy to share. Often open-source tools can be used to reduce costs, though we recommend the use of mature and well-supported technologies.

Data protection needs to be considered when storing personal data online. It may be possible to overcome this by not collecting any personal information, but this limits the potential for communication with people and personalised feedback. Advice must be sought to make sure that any online data storage in the UK complies with the Data Protection Act.

Validation, quality assurance and verification

One of the key aspects of data collected by citizen science projects is that it needs to be 'of known quality'. 'Known quality' can be either 'guaranteed to be accurate' (e.g. through verifying photographs) or achieved by quantifying the degree of error or bias.

One of the most cost-effective ways of ensuring high data quality is to thoroughly test your protocols (Tweddle *et al*. 2012). Through this process you can quantify errors in measurement/ identification and improve protocols where necessary. For some projects, records are only accepted if there is accompanying information (e.g. a photograph), especially for unusual records. This conservative approach may result in the discarding of genuinely interesting data points, so should be undertaken with care.

For other data, quality will be affected by random error and bias. Random error will increase the 'noise' in the data (for example, inaccuracy in making counts), thus making it more difficult to accurately discern signals from the data. However, most error is likely to be some form of bias (a systematic error) and this can vary due to many different factors, including people's experience. This bias needs to be quantified and explicitly accounted for in the analysis. One often overlooked source of error is the lack of a record. People are most likely to record the presence of something rather than its absence or record something out-of-the-ordinary, thus causing systematic bias in the data.

Communication

Communicating with the target audience is clearly a vital aspect of citizen science. Communication via the mass media is appealing for many organisers of citizen science, but it is risky to rely on journalists to promote a project. It is wise to explore alternative, more stable, routes of communication (e.g. newsletters of interest groups) in addition to the mass media. Social media (e.g. Twitter and Facebook) has opened up new opportunities for promoting projects and communicating with participants, and news can spread quickly by 'word-of-mouth'. Workshops and training sessions can provide invaluable face-to-face contact with project participants. Varied approaches to communication will ensure projects are promoted in a way that meets the requirements of the diverse range of potential participants.

Final thoughts on choosing and using citizen science - continued

It is also important to consider what and how you communicate (Blackmore *et al*. 2013). Not only do you need to communicate the 'why?' and 'how?' of your project, but you should also communicate the 'so what?'. For some projects, participants might expect action in response to their observation but this may be beyond the scope of the initiative e.g. getting littered water courses cleaned on their behalf. For some other projects, participants might be asked to collect data that leads to a response they find unacceptable, e.g. eradication of an attractive but invasive non-native species. It is important to consider and address people's expectations early in the project.

Participant safety

Although citizen science should only be considered if it can be undertaken by volunteers safely, no activity is risk-free. Therefore risk assessments should be undertaken and sources of risk in the instructions to participants should be removed, as far as possible. The risk, and its reduction, should be clearly and succinctly communicated to participants. The level of support and training will influence the types of risk that are acceptable. For example, when assessing water quality, members of the general public might be asked to make observations from the bankside only, while actually wading in the water might be deemed to be acceptable if personal training was provided.

Legislative implications

For some subjects that are amenable to a citizen science approach there may be important legislative implications that need to be considered (see the excellent report by Bowser *et al*. 2013). For example, what are the implications of volunteers being asked to report notifiable diseases on someone else's land, both on the landowner and the agency given the task of responding? If the citizen science data leads to action by regulatory authorities, then are the data sufficiently accurate and robust? If the citizen science data is used to derive an indicator on which government or agencies commit to act, then are the data sufficiently accurate and robust?

Conclusion

Citizen science can be a brilliant way to undertake excellent science and engage people with important and relevant issues. We hope that this 'Guide to Choosing and Using Citizen Science' has provided you with confidence to develop meaningful, useful and successful citizen science projects. Developing and supporting citizen science is hard work, but it should also be enjoyable and very rewarding both for organisers and participants. So, please see this guide as a starting point that you can add to and adapt to meet your needs and above all remember to have fun... enthusiasm is infectious!

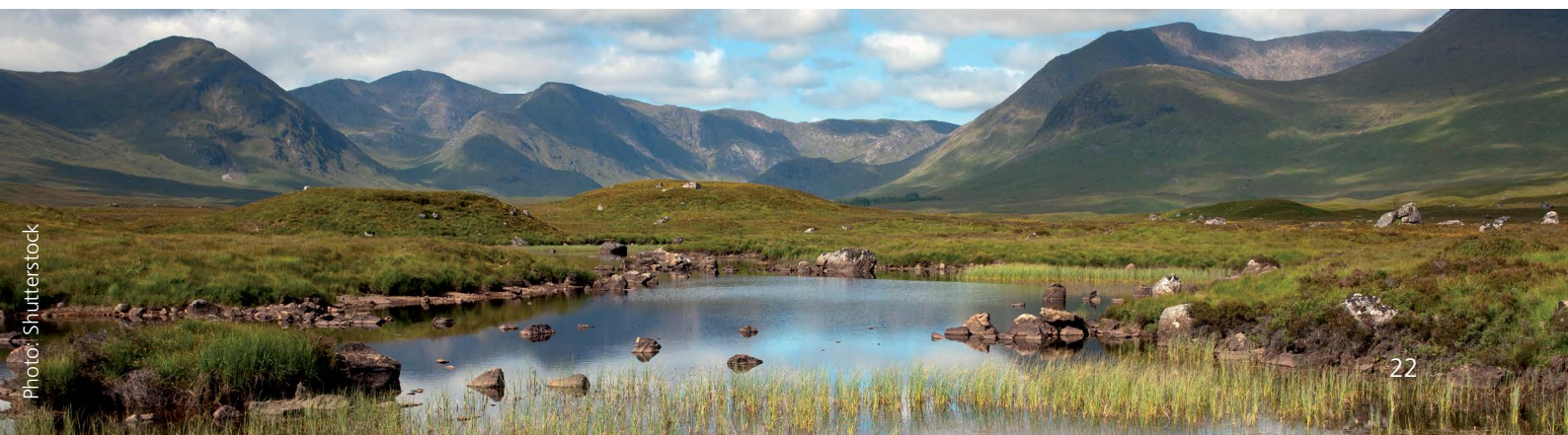


Photo: Shutterstock

References and resources
References

Blackmore, E., Underhill, R., McQuilkin, J. & Leach, R. (2013). *Common Cause for Nature: Finding Values and Frames in the Conservation Sector*. Public Interest Research Centre, Machynlleth, Wales.

Bonney, R., Ballard, H., Jordan, R., Mccallie, E., Phillips, T., Shirk, J. & Wilderman, C. (2009). *Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education. A CAISE Inquiry Group Report*. Center for Advancement of Informal Science Education (CAISE), Washington, D.C.

Bowser, A., Wiggins, A. & Stevenson, R. (2013). Data Policies for Public Participation in Scientific Research: A Primer. DataONE: Albuquerque, NM.

Cornell Lab of Ornithology. (2013). Citizen Science Toolkit, http://www.birds.cornell.edu/citscitoolkit/toolkit

Defra. (2012). *UK Biodiversity Indicators in Your Pocket 2012*. Department for Environment, Food and Rural Affairs, London.

Nerbonne, J.F. & Nelson, K.C. (2004). Volunteer macroinvertebrate monitoring in the United States: resource mobilization and comparative state structures. *Society and Natural Resources*, **17**, 817–839.

Pocock, M.J.O., Chapman, D.S., Sheppard, L.J. & Roy, H.E. (2014). A Strategic Framework to Support the Implementation of Citizen Science for Environmental Monitoring. Final Report on behalf of SEPA. Centre for Ecology & Hydrology.

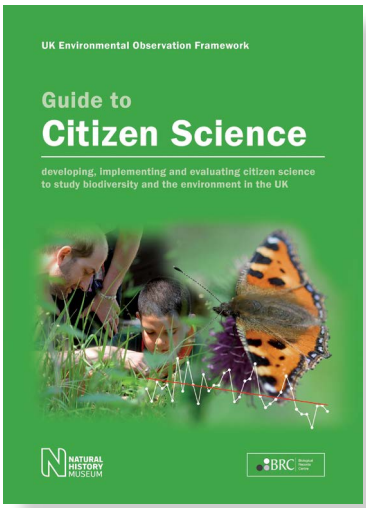
Pocock, M.J.O. & Evans, D.M. (2014). The success of the horse-chestnut leaf-miner, *Cameraria ohridella*, in the UK revealed with hypothesis-led citizen science. *PLOS ONE*, **9**, e86226.

Rotman, D., Preece, J., Hammock, J., Procita, K., Hansen, D., Parr, C., Lewis, D. & Jacobs, D. (2012). Dynamic changes in motivation in collaborative citizen-science projects. *Proceedings of the ACM 2012 Conference on Computer Supported Cooperative Work*, 217.

Roy, H.E., Pocock, M.J.O., Preston, C.D., Roy, D.B., Savage, J., Tweddle, J.C., Robinson, L.D. (2012). *Understanding Citizen Science & Environmental Monitoring. Final Report on Behalf of UK-EOF*. Centre for Ecology & Hydrology, Wallingford, Oxfordshire.

Silvertown, J. (2009). A new dawn for citizen science. *Trends in Ecology & Evolution*, **24**, 467–71.

Tweddle, J.C., Robinson, L.D., Pocock, M.J.O. & Roy, H.E. (2012). *Guide to Citizen Science: Developing, Implementing and Evaluating Citizen Science to Study Biodiversity and the Environment in the UK*. Natural History Museum and Centre for Ecology & Hydrology for UK-EOF, London, UK.



References and resources
Resources and links

An example of a bespoke technology designed for specific purpose and audience is the NatureLocator smartphone apps http://naturelocator.org/ and the online databases of many extant citizen science projects.

Examples of adaptable template-type platforms

Epicollect http://www.epicollect.net/ for mobile applications

PyBossa http://crowdcrafting.org/ for crowd-sourcing

CitSci.org http://www.citsci.org/ for data collection and visualization

Ushahidi http://www.ushahidi.com/ for crowd-sourced mapping

OpenTreeMap http://www.azavea.com/products/opentreemap/ for mapping trees

Examples of flexible and user-friendly data systems are:

Indicia (http://www.indicia.org.uk/) a database toolkit developed by the Centre for Ecology & Hydrology, which is purpose-designed for the collection, visualisation, verification and sharing of biodiversity data and could, with adaptation, be used for the collection of environmental data as well).

Google code (http://code.google.com/)

About the authors

Michael Pocock
(michael.pocock@ceh.ac.uk) is an ecologist at the Biological Records Centre within the Centre for Ecology & Hydrology. He co-leads Conker Tree Science and has been involved in several other citizen science and public engagement with science projects.

Daniel Chapman
(dcha@ceh.ac.uk) is a spatial ecologist who works on modelling the spread of invasive species and studying phenology, such as the timing of flowering in spring, by using biological recording data collected through citizen science.

Lucy Sheppard
(ljs@ceh.ac.uk) is a fellow at the Centre for Ecology & Hydrology, working on the impacts of pollution on ecosystems. She helped develop a 'lichen-based index to nitrogen air quality' that has been used for citizen science.

Helen Roy
(hele@ceh.ac.uk) is an ecologist at the Biological Records Centre within the Centre for Ecology & Hydrology. She has enjoyed many opportunities to develop and participate in citizen science, and coordinates the UK Ladybird Survey.

Photo: Shutterstock