Citizen Science Framework Review

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Informing a Framework for Citizen Science within the US Fish and Wildlife Service

Jennifer Shirk and Rick Bonney

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Citizen Science Framework Review:
Informing a Framework for Citizen Science within the US Fish and Wildlife Service

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by Jennifer Shirk and Rick Bonney, Cornell Lab of Ornithology

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INTRODUCTION

The term citizen science describes partnerships between the public and professional scientists to address questions and issues of common concern. Usually when people refer to citizen science they mean projects for which members of the public collect, categorize, transcribe, or analyze scientific data (Bonney et al. 2014). Over the past two decades citizen science has become very popular, and thousands of citizen science projects now engage millions of participants around the world. Projects cover a breadth of fields ranging from astronomy to zoology. Citizen science is used as a tool for increasing knowledge about the natural world, for achieving environmental conservation, and for increasing public science literacy.

A growing body of research is showing that well-designed citizen science projects can achieve outcomes such as:

- peer-reviewed scientific publications (Dickinson et al. 2010, Theobald et al. 2015)
- access to landscape-scale data, necessary for informing restoration efforts (Cooper et al. 2007, Devictor et al. 2010)
- influence on environmental policy and conservation (McKinley et al. 2015)
- increased public knowledge, attitudes, and behavior toward science (Bonney et al. 2009, Bonney et al. 2015)
- cost-efficiencies in data access and public engagement (Conrad and Hilchey 2010)

To achieve any of these benefits, projects must be designed, managed, and supported strategically.

Although citizen science can take many forms, most projects fall into one of two major categories. The first includes projects for which volunteers **collect data** that can be used in organized scientific research. Data collection projects are well known to ecologists and natural resources managers because they have been in existence for decades (the Christmas Bird Count[1] began in 1900), and data from some projects, such as the North American Breeding Bird Survey[2], have been used to inform natural resources policy and planning efforts (McKinley et al. 2015). Participants in data collection projects can benefit science by gathering huge amounts of data, often over wide geographic areas and over long periods of time.

The second category of citizen science projects includes those for which members of the public **manage, transcribe, or interpret large quantities of data,** for example, photographs of animals and their behaviors taken by cams around the world. Participants in data processing projects play a critical scientific role by helping to examine and analyze what would otherwise be unmanageable amounts of information.

Because data-collection projects are likely to be the most useful form of citizen science for the immediate research and education needs of the US Fish and Wildlife Service (USFWS), we have focused on data-collection projects in this report. However, data processing projects also could be useful to some refuges for certain needs, and a future report could investigate their potential.

Overview of data-collection projects

Data-collection projects take place along a gradient of scales of size, geography, and time. At one extreme are “contributory” projects (Bonney et al. 2009), which are typically large-scale, top-down, scientist-driven projects designed to address questions or issues requiring large amounts of data to be collected across wide geographic areas over long periods of time. One example is eBird[3], which collects 5 million observations of birds each month from locations across the globe. Data from contributory projects can be used for purely scientific aims—for example, to document changes in range distributions of plants or animals—or can be applied to conservation efforts. For example, eBird data are used by The Nature Conservancy to determine areas in the central California valley where the organization can pay farmers to flood their fields during times of peak waterfowl migration (Robbins 2014).

[1] http://www.audubon.org/conservation/science/christmas-bird-count
[2] https://www.pwrc.usgs.gov/bbs/index.cfm
[3] http://ebird.org

At the other extreme are "co-created" data-collection projects. Sometimes called "Community Science," co-created projects often focus on local or regional environmental or policy issues. They may be developed by members of the public who reach out to scientists for assistance, and often they involve participants in data interpretation and dissemination in addition to data collection. For example, the West Oakland Environmental Indicators Project empowered individuals living in an economically depressed neighborhood to collect air-quality and health data documenting the degree to which air pollution affects local residents (West Oakland Environmental Indicators Project 2013).

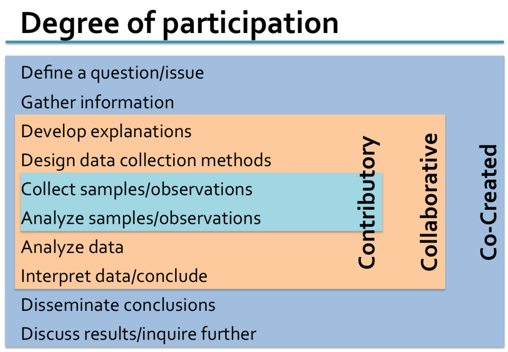


Figure 1: Three models of "data-collection" citizen science by degree of participation in the research process (based on Bonney et al. 2009; see also Haklay 2013, Appendix G for another interpretation). Projects may sometimes similarly be differentiated as "top down" and "bottom up."

Research is showing that participant engagement will affect project outcomes (Stepenuck 2013). Pros and cons of different models of engagement should be considered early on in the project-development process.

Citizen science efforts cannot always be categorized easily. For example, some large-scale data-collection projects have distinct goals for policy and management and can influence policy at local or regional levels as well as nationally. Some community-based projects yield outcomes with large-scale implications. Nevertheless, understanding these general project categories is useful when considering the goals of developing or implementing a citizen science approach to meet agency needs.

Despite its potential benefits, citizen science isn't a solution to every problem. It requires investments of time and resources by multiple parties with distinct needs, all of which need to align for mutual benefit (for more, see section on Identifying Goals). The merits and design needs of citizen science should be considered thoughtfully for the specific circumstances where it might be employed.

This Independent Science Review was created to inform development of a framework for citizen science within the USFWS. As a guide for the strategic use of best practices, a citizen science. framework can facilitate the following:

- Deciding when and how to employ a citizen science approach
- Guiding the strategic design, use, and/or implementation of citizen science
- Determining how to efficiently and effectively fund citizen science efforts
- Articulating and ensuring the value of citizen science to the USFWS

To inform this process, we conducted interviews with eleven experts who themselves have developed frameworks or strategic analyses of citizen science (Appendix A). We also compiled and synthesized information from foundational documents on design, development, and support of citizen science projects (Appendices B and C).

This process revealed key components of citizen science design and management that should be considered in the development of a framework. These include five stages of strategic development and implementation (identify goals, establish capacity, design/refine, manage, and apply/adapt). These also include two interests that must be considered throughout the lifecycle of a project (participant engagement and sustainability/accountability).

The next section of this document describes each of these five stages of development and evaluation. After that we discuss the two overarching concerns, participant engagement and sustainability/accountability. Finally we summarize options and advice offered by interviewees regarding the utility and development of a framework for citizen science, and the opportunities and responsibilities for an agency taking on the role of facilitating this work.

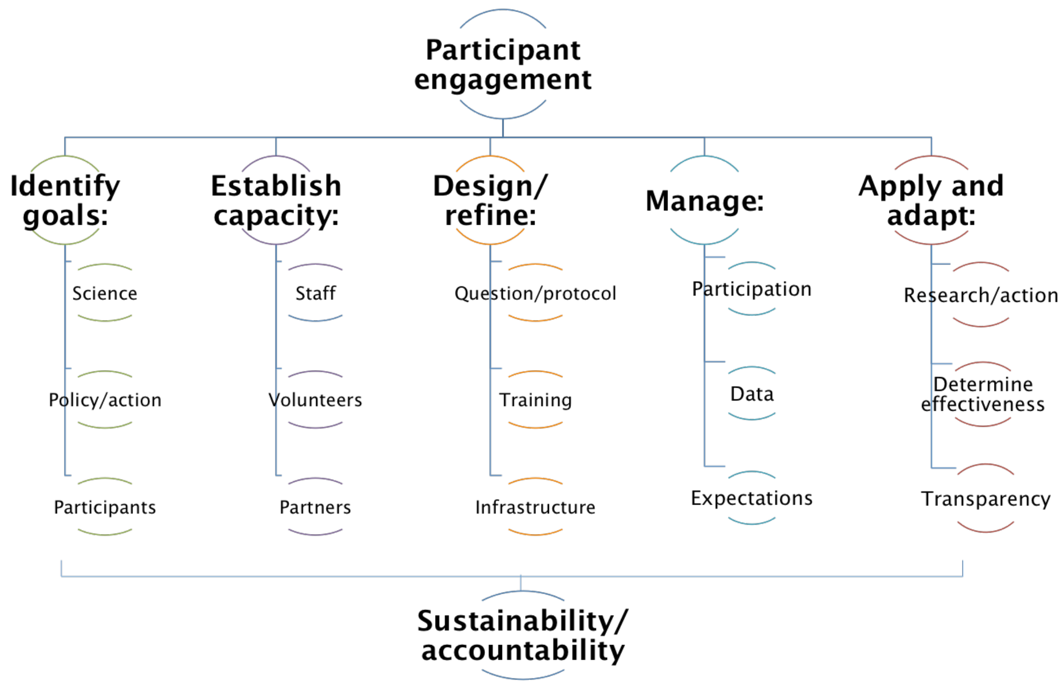


Figure 2: Suggested components of citizen science design and management to consider in developing a framework. These five categories emerged from the process of conducting this Independent Science Review.

KEY COMPONENTS

Identify goals

Research in the field of citizen science increasingly supports the idea that project design will influence project outcomes. Below we cover insights on goals for science, for policy or action, and for participants. Citizen science can achieve outcomes in all of these categories, especially when possibilities are considered and goals are articulated up front, in order to inform careful and intentional design (Shirk et al. 2014, see Appendix H).

Goals should be realistic and relevant in regards to project scale, participant interests, and agency priorities. Setting realistic goals will require questioning assumptions about such things as who might use resulting data, whose goals should take priority, and what counts as success. Goals (for the short, medium, and longer term) should enable demonstration of success both internally and externally.

One of the first assumptions to question is whether citizen science is the best approach given the goals and resources at hand (Figure 3).

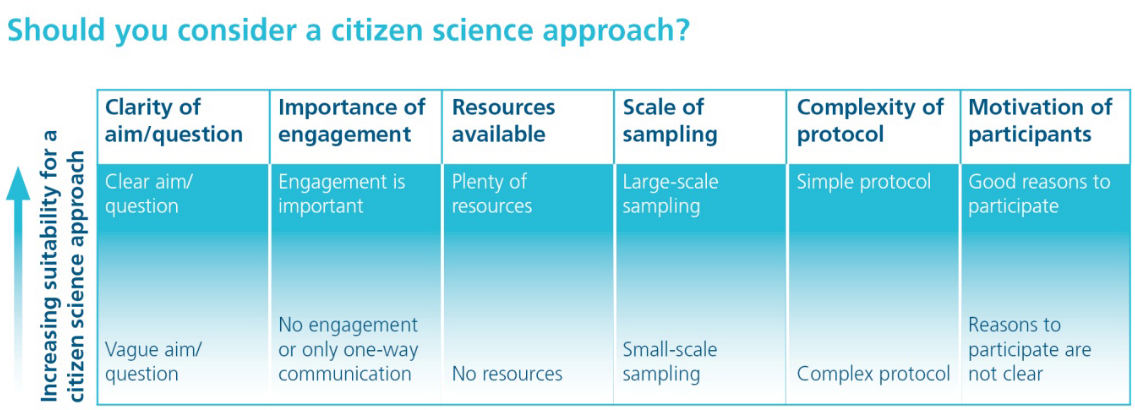


Figure 3: Example decision framework for citizen science from Pocock et al. (2014). These are guidelines, not rules - not all criteria must be met, and creative solutions may be found to increase suitability. Also consider that scale may be either spatial or temporal, and includes a degree of granularity – community-based monitoring, for example, provides data over a relatively small spatial scale but can provide greater resolution of observations within that space and over time that is otherwise unfeasible.

Being clear about goals will inform choices as to whether and how citizen science can best be employed. This can be accomplished using a logic model (see, for example, worksheets available in Phillips et al. 2014). Others may turn to planning resources such as concept maps or results chains (e.g., Foundations of Success 2007).

Science

Citizen science enables a different approach to research, allowing new kinds of questions to be answered. Engaging volunteers can enable data collection at previously unthinkable scales, and can also provide additional insights and expertise. Technology makes it possible for participants to analyze, collect, and manipulate data in new ways. In some cases, citizen science data may already be available, in unexpected forms or places such as naturalists' journals or traditional ecological knowledge. Citizen science data can stand alone, or can complement other data to shed new light on old problems.

The most common question about citizen science is: "are these data any good?" Data quality is a real issue, with legitimate concerns, but can be addressed with realistic goals and careful design. Given that "quality" can be defined in many ways (Sheppard and Terveen 2011), and that every dataset has some degree of limitations, more helpful and productive questions can include:

- What level of data quality do I need to address these goals?
- What can I do to improve data quality?
- What can I learn from these data given its level of accuracy or precision?

Criteria for scientific success include setting goals for collecting data of known quality and drafting a Quality Assurance Project Plan (QAPP; US EPA 1996). Such a plan can include steps like equipment calibration, training, protocols, or the development of sophisticated infrastructure that manages data entry. With such a plan in place you can get out ahead of potentially problematic situations, and be prepared to justify the use and usefulness of citizen science.

One strategy for increasing the scientific value of citizen science is to define the data needs and connect with data users from the start. At the same time, be aware of the interests and capabilities of volunteers in regards to skills, interests, and the time they can invest. This can help set realistic and appropriate standards for the scientific products that can result.

One interviewee in this process stated that data quality all comes back to realistic expectations and careful project design: "if you can't use data collected by citizen science to manage or to make decisions, it's your own fault for not designing the project right."

Participants

Citizen science has little chance of attracting and retaining participants unless the goals and motivations of those participants are understood and appreciated. Goals will vary across project types and topics, although one motivation that seems to cut across efforts is the opportunity for their engagement to make a worthwhile contribution to research or discovery. In cases of community-based monitoring (CBM), action may be the most valuable output for participants.

Participation in citizen science is often discussed in the context of education. Citizen science has great potential to advance learning outcomes, which can include such things as behavior change and the development of social capital as well as gaining skills and content knowledge (e.g., Bonney et al. 2009). If focusing on education, it is worth thinking carefully about how to articulate and communicate learning goals that are relevant to participants. Consider factors such as state standards for learning or volunteers with an already high level of knowledge or expertise.

One approach to engaging participants – whether individual volunteers, educators and their students, or community groups – is to clearly communicate project goals and recruit participants who share them. A different approach is to listen to community needs and jointly determine project indicators and possibly even project goals (see Pandya 2012). Participants, particularly in communities, may come up with questions, share their best-guess answers, and take part in developing a conceptual model to guide project design and implementation.

Such an approach may be particularly helpful in situations of contention or even conflict related to management choices. One strategy in such situations is to co-develop a concept map for research and management that can make explicit where goals and assumptions are shared and where they're different. This can also help articulate areas of uncertainty, and the indicators needed to build an understanding of the issue.

Policy/action

Particularly in agency contexts, data likely are collected for reasons that go beyond addressing a scientific question. Whether to inform a particular management decision or monitor a resource for the long term, citizen science can fill important gaps in addressing policy needs and informing action.

Identifying data purposes and users from the outset can also help articulate the parameters of data needed to address the issue at hand. Beyond considering the necessary quality of data, addressed above, such parameters may also include:

- Scale – do you need data from a single site or across a landscape, such as to inform restoration efforts? (Clement 2014)
- Jurisdictions – do you need data from outside the bounds of your refuge? (Haklay 2015)
- Timeliness – how soon must decisions be made and how quickly must data be collected to be relevant? (Vaughan et al. 2003)

Policy, management, and action are also influenced by more than scientific data. In Canada, where traditional ecological knowledge is critical for informing some decisions, community-based monitoring provides the opportunity to engage local insights from First Nations communities. It is important to recognize, however, that while citizen science can enhance or augment other public input techniques, it should not be considered a replacement for those efforts.

Establish capacity

Establishing capacity involves, first and foremost, recognizing where it already exists. It is useful to identify and acknowledge the particular contributions that individual staff, participant groups, and partnering organizations (whether agencies, universities, NGOs or others) can bring to project efforts. By doing so, you can build on known strengths and target where additional capacity needs to be developed.

Before building capacity, consider first where you can broker connections. An agency can facilitate networking, both to identify and align with complementary efforts and to leverage good ideas. Connections may be within the agency, across agencies, or with other institutions and programs. It is particularly advantageous to work with those who are already invested in the process, and who have shared or complementary goals.

Capacity can come in the form of skills, tools, connections, or resources (monetary or otherwise; see Box 1). Providing funding for projects and programs affords a certain level of control over the priorities that are addressed, such as efforts to collect badly needed data or respond to community concerns.

It is important, however, to build capacity with an eye towards sustainability. While citizen science can be economical, it is not free – projects need to be resourced, and most projects that rely on participant engagement need to establish connections and trust that will last for the long term.

BOX 1: Wisconsin's Citizen-Based Monitoring Network

The Wisconsin Department of Natural Resources has, since 2004, worked to build capacity for practitioners conducting environmental monitoring in the state. They provide connections among projects via a directory and occasional conferences. They offer lists of resources for monitoring. And their Partnership Program mini-grants offer up to $5,000 to organizations for project start-up or enhancement.

The Partnership Program's focus is revised each year to align with DNR priorities. A rigorous proposal and review process ensures thoughtful ideas and quality work. Grant reporting requirements help the agency show their impact per dollar spent, with recent reports indicating a return of three dollars for every dollar invested, as measured in volunteer time.

Details on Wisconsin's Citizen-Based Monitoring Network and the Partnership Program are available at: http://wiatri.net/CBM/

Volunteers

Before assuming that establishing capacity for volunteers means providing training, consider this: those who opt to participate more than likely bring some level of skill, interest, insight, or commitment to the project. Begin by understanding, acknowledging, and building upon that capacity. This may include amateur expertise (such as can be found in the birding community), traditional ecological knowledge (which can inform, shape, and/or complement agency-driven research), or even ancillary skills such as for social media or community organizing. By recognizing these contributions and the value of what participants bring to the project beyond "free labor," you can more fully acknowledge participants as critical partners and tailor any necessary training to their particular needs.

Also consider, before developing trainings, the level of skill that is necessary for your data needs. Some research areas are particularly challenging, such as plant ID, but can be done where there is a high level of interest and commitment and/or where significant training and oversight is provided. Some types of research questions can be easily undertaken by participants with existing skills, support materials, and/or appropriate training

Staff

Working on research with volunteer participants calls for a diverse set of skills. In rare cases, staff will gravitate towards this work with the necessary skill set, and it is important to reward that. More often, the necessary skills will need to be taught, or collaborations established between scientists and staff with background in communications, engagement, or action research. In those cases, it is useful to have communicators/educators working side by side with scientists in the development and implementation of projects.

Certain citizen science approaches call for partnering closely with communities. This requires additional skills that scientists often aren't trained in, and working relationships that even educators and visitor services staff may be challenged to facilitate. In such cases it can be helpful to identify, hire, or partner with someone who can focus on the process of building and maintaining collaborations with community partners.

In general, it is critical to provide employees with enough support, encouragement, training, and a sense that their investment in citizen science will be rewarded as part of their job.

Partners
Partnering is a smart approach to project efficiency. With a wealth of citizen science projects and infrastructure available, it is worth reviewing what already exists in relationship to your goals before making a decision about where to invest (lists of projects and resources are available at SciStarter[4] and CitizenScience.org[5]). If you have already identified, for example, that your primary interest in citizen science is to provide an engaging research experience for visitors, the most cost-efficient approach could be to partner with and locally implement an existing project such as Nature's Notebook[6]. Even with the capacity to build new project infrastructure, partnering with complementary efforts can enhance – rather than segregate – datasets, amplifying the research potential in addition to saving resources.

Beyond other existing citizen science efforts, it is worth considering how the envisioned project would fit with other research and monitoring already underway, whether within the agency or with a region. Partners at the level of federal, state, tribal, or local level governments can enhance the potential usefulness for management and decision-making.

Design/refine

Involving partners and other stakeholders early in the process of project design can increase investment and enhance outcomes. When relevant to the scale of the issue and question, volunteer input into project design increases the types and likelihood of management outcomes (Danielsen et al. 2007, Stepenuck 2013).

As one interviewee put it, "big things start small." Pilot where possible – with the intended user group – everything from protocols to web infrastructure. Ultimately, project design goes hand-in-hand with project evaluation (which begins with defining goals), and should be considered an ongoing and iterative process (see Phillips et al. 2014 for guidance and resources).

Question/protocol
Intended data users should play a key role in defining the research question and/or monitoring protocols. These should be developed in alignment with goals and capacities.

Where possible it is worth adopting standardized and vetted protocols used by others. This is said with the recognition that it is almost always necessary to customize standardized protocols based on local or regional conditions. It can be possible to reconcile these interests by having tiers of protocols: a protocol tested nationally at a scale that consistently measures a given parameter can be paired with an additional protocol tailored to regional or local needs.

Guiding principles for developing data models have been adapted to include volunteer monitoring (e.g., Sheppard et al. 2014). Recommended attributes cover the basic who, what, where, and when, stated as:

[4] http://www.SciStarter.com
[5] http://www.CitizenScience.org
[6] https://www.usanpn.org/natures_notebook

- Observer
- Object/organism
- Location
- Visit to location (separate by time)
- Site characteristic (environmental)

Data about observers and their patterns of data collection can be critical for citizen science. When handled carefully – and ethically – such information can serve as metadata that help describe the merits of the research.

Training

As discussed in the section on establishing capacity, recognizing the skills that participants bring to a project can help target the type of training that is necessary. Where training is necessary, project scale will to some degree determine how training is delivered: national-scale projects may need to rely on manuals or videos, whereas local-scale projects can provide in-person sessions. Adopting an existing project may provide the best of both worlds, allowing a local site to design and run training sessions around support materials that have already been developed and vetted.

Quality control efforts can be built into training and thus established as a routine part of project participation.

Infrastructure

Plans should be made early on for the infrastructure necessary to capture, manage, store, and share project data, where appropriate. This can include both data collected by volunteers and data about volunteers (contact information, level of training, hours contributed, etc.). Infrastructure may be high or low tech, but is most efficient if designed for sustainability (see also information on data management).

Many existing citizen science projects can provide the core infrastructure around which a regional or topical effort can be developed (e.g., iNaturalist[7]). An increasing number of technology platforms and tools are also arising to facilitate custom citizen science project design. These include platforms for app development (e.g., Sapelli[8]), sensor design (e.g., PublicLab[9]), mapping (e.g., collaborative geomatics[10]), and overall data and volunteer management (CitSci.org[11]).

In developing project infrastructure it can be advantageous to plan for landscape-scale data interoperability (see Newman et al. 2011). In some management cases, such as restoration (Clement 2014), it is necessary to have access to broader-scale data even when your project may not have off-site jurisdiction.

Infrastructure can also mean building data sharing relationships in circumstances where project participants and community members have a role in supporting or informing management. Data sharing relationships are less formal and binding than integrated management scenarios. One expert advises however, that establishing formal co-management agreements can be time

[7] http://www.inaturalist.org
[8] https://www.ucl.ac.uk/excites/software/sapelli
[9] http://publiclab.org/
[10] McCarthy, Daniel D. et al. (nd). The Various Applications of Collaborative Geomatics Systems - an Interactive, Web-based Mapping Tool - in Remote and Isolated First Nation Communities in Sub-Arctic Ontario, Canada. Online article, accessed 17 May 2015: http://t12.cgpublisher.com/proposals/131/index_html
[11] http://citsci.org/

consuming, costly, and apt to get hung up in policy, and that these relationships can happen organically when agencies are open to and prepared for local collaborations.

Manage

Fewer best practices have been documented for some of the more procedural tasks of managing a citizen science project. Attention here, however, can be critical for sustainability, with the need to anticipate and respond to ongoing needs of participation, data management, and expectations of all partners. Consider a project as you would a well-run lab, outlining an annual timeline of expectations, plans for activities, and evaluation efforts.

Participation

While some think about managing participation in terms of volunteer retention, it is as important to value participation consistency and reliability. Some projects write and advertise job descriptions for volunteers, presenting those details at a volunteer's first orientation session in terms of *responsibilities*. Expectations regarding time commitments and quality standards should be clearly communicated. Organizers should also be reasonable when setting those expectations and understand the value of the time and efforts volunteers are contributing.

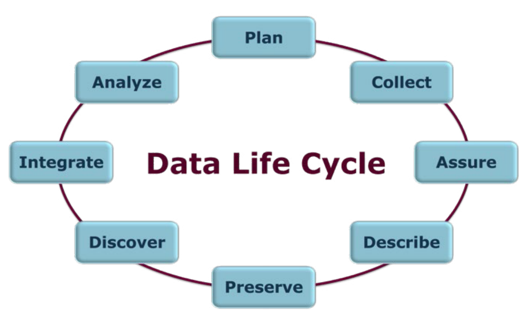
Projects should acknowledge and celebrate the contributions of volunteers and their roles in project outcomes. Where appropriate, awards, ceremonies, or recognition events can help to this end. In community-based monitoring, ongoing efforts towards reciprocity may be more appropriate than a ceremonial acknowledgment of contributions (see section on participant engagement for more about reciprocity).

Data

Questions about ways to manage and store data should be considered early in the process of designing a project. Data management for citizen science is not much different than data management for other research efforts, with two basic exceptions: 1) projects should also be prepared to manage data about participants and participation efforts, both as descriptive metadata and as a means of managing volunteers themselves, and 2) there is greater cause to make data accessible and useful for participants and partners.

There are growing resources available for environmental science, more generally, in how to plan for data management, particularly through the NSF-funded DataONE initiative (DataONE.org[12]). A general rule of thumb is to start by having a data management plan in place, one that is user-friendly. It can also be helpful have a data liaison in place so that interested parties (whether staff, partners, or volunteers) can access the needed information in an organized fashion.

Figure 5. This data life cycle is not unique to citizen science, but a DataONE handbook (Wiggins et al. 2013) highlights unique concerns of citizen science for each phase.



[12] http://www.DataONE.org

Because citizen science necessitates having data about participants, and because it often involves numerous partners wanting access to project data, it is critical to also have data policies. These policies articulate how the project will manage such issues as privacy and terms of use for any data. Guidance on developing data policies is available in a DataONE Data Policy Guide (Bowser et al. 2013).

Expectations
While it is important to set expectations, such as those discussed for volunteers, it is just as important for a project to manage and respond to the expectations of key constituents, including volunteers, agency administrators, data users, and communities. Even better is to understand and anticipate expectations of different partners, to share relevant information in a timely way to pre-empt questions or concerns.

Regular (even early) updates and feedback are a critical way of sharing progress, but managing expectations involves more than just reporting. Projects should help constituents understand not just what is happening, but also "How do results apply to me? Where do I fit into this picture?" Understand constituents' interests and goals so that you can share both results and the meaning of the results, to help make the numbers make sense to participants and the results relevant to what they need to know.

See also the section on Transparency regarding the use of data.

Apply and adapt

While project management is ongoing, occasional focused activity is necessary to move from a phase of ongoing work towards accomplishing targeted goals.

Research/action
Citizen science data analysis for research can involve making sense of complex and sometimes messy datasets. Although careful planning and alignment of questions with protocols can help with clarity, citizen science data can at times call for sophisticated analytic techniques to help account for the complexities of multiple observers, data on effort, and sometimes opportunistic observations. Citizen science can be particularly useful when paired with other datasets, which can call for integrating data and assimilation of data produced in different ways.

Where efforts involve community-based monitoring (CBM), local observers should also be involved in the process of analyzing data (see Box 2). This calls for structure and processes that are inclusive, effective, and efficient. Given institutionalized data pipelines that are set up to draw on agency information, it may take some time before CBM data are put into use for research. However, CBM data can influence decisions about management of government-owned lands, or around general policies that inform broader decisions.

BOX 2: ALLARM data analysis trainings

The Alliance for Aquatic Resource Monitoring (ALLARM) project, based at Dickinson College in south central Pennsylvania, acts as a service provider in support of local and regional water quality monitoring. In addition to facilitating community development of questions and protocols for data collection, ALLARM staff provide training sessions that help communities interpret their data.

ALLARM has come to recognize that local community members know the on-the-ground water resources better than visiting scientists, and can therefore help efficiently focus analyses on likely problem areas or suggest explanations for trends. ALLARM staff share technical skills such as reading box-and-whisker plots. Together, these facilitated sessions help communities tell the stories in their data, and have resulted in numerous management reports and actions.

For more information on this process, see ALLARM 2010.

Transparency

From the outset it is important to be up-front and transparent about how data are generated, how they will be made available, and how they are going to be used. Regular feedback should be provided both on what the research is showing and on ways the data or research results are being used. Partners and participants should be able to see how citizen science is being used to inform decisions, and ideally have access to the data and analyses. Openness and transparency can require investments in infrastructure and in time – it is worth considering this in terms of an investment towards community/participant trust, ongoing participation, and perhaps even unique insights or actions.

There will be circumstances where full transparency and openness will raise concerns or may not even be possible. For example, location data for endangered species often need to be obscured. They can also at times be contentious, or carry legal implications. There is a particular set of issues to consider when data have direct management or policy implications, such as for species management, habitat restoration, or game harvest. Transparency and openness can raise concerns about unanticipated and potentially unsanctioned data usage.

Consider also the role that citizen science research and participation can play in more formalized co-management arrangements. These involve an acknowledged, formal power sharing relationship regarding who has a say on one specific issue. In co-management, volunteer community members would take part in a mixed stakeholder committee working to inform the entire research and monitoring process, ensuring procedural transparency.

Determine effectiveness

The process of evaluation begins early in project design, by setting clear goals. Ultimately, the time comes to determine the effectiveness of efforts in reaching those goals.

Evaluation involves looking back at goals, assessing what has worked, and setting new goals. This includes seeing how well a project works for all partners. Given that citizen science projects often have multiple goals, such as for participant learning, scientific research, and conservation action, evaluation priorities may need to be set, and/or different kinds of evaluation efforts be employed. One challenge is how to gracefully identify and address projects that work from those that don't.

Adaptive management is one way to frame the iterative process of project design and redesign. The cyclic nature of the approach is designed to facilitate continuous learning, improvement, and adaptation, to ensure that the effectiveness of project activities improves over time, and that activities can respond to changing needs and conditions (Williams et al. 2009). Other tools include logic models and conceptual diagrams. For background on how to approach and plan for evaluation in citizen science, with a particular emphasis on learning outcomes, see Phillips et al. 2014.

OVERARCHING CONSIDERATIONS

Two related and overarching considerations should be kept in mind throughout all of the previously discussed stages of designing and implementing a citizen science project: participant engagement, and the sustainability and accountability of a project to those participants and other partners.

Participant engagement

Participant engagement in research is what sets citizen science apart from conventional science. Although it is not necessary to involve participants in all phases of project design and management, the implications and opportunities of participant engagement should be considered in all decisions.

The depth of participant engagement in the research process will depend on the project needs and scale. Research does show increases in policy and management outcomes when volunteers play more roles, specifically if they go beyond data collection to also help with tasks such as selecting sites, analyzing data, and communicating results. In water quality monitoring contexts, recent surveys reveal a positive relationship between depth of participation and the reported number of outcomes for policy and management. These include data used for restoration and designation, direct outcomes on the resource (such as setting or enforcing rules and regulations), civic engagement (writing letters, giving presentations, testifying), and even changing organizational approaches to management.

Regardless of the depth of participation, think about issues of reciprocity throughout the design of a project. This has both practical and ethical dimensions. Practically, participants who don't feel valued, listened to, or supported will not remain involved. From an ethical perspective, keep in mind the power dynamics that are inherent when a government agency leads monitoring efforts with implications for local economic security or environmental justice. Taking an asset-based approach to collaboration, focused on the strengths different players bring to the table, can help build trust and relationships.

Ultimately, be genuine in approaching public engagement as a relationship, not just to "check the box" of expectations for public outreach. Consider work with the public as a long-term investment by working with communities at the outset. Earning the trust of the community and the respect and dedication of individual participants will set the project up to be more efficient and sustainable.

Sustainability/accountability

Good citizen science doesn't need to require a lot of money. But with an eye towards building trust and sustainable collaborations, citizen science may require money for a longer period of time. In Nova Scotia, organizations that were provided with seed funding for a long period of time have established capacity such that they're now working more efficiently than government monitoring programs. Organizations with limited capacity can't sustain a core staff, and thus are hard pressed to establish any kind of consistent work by volunteers. A little bit of money, particularly for consistent staffing, can go a long way towards enhancing the quality of a project in terms of both data and reciprocity for participants.

Building strong partnerships can be one strategy for project sustainability. Partners will put in their own funding and own time if invested in shared goals. Consider municipalities, universities, friends' groups – any organization that may have interests that are symbiotic with the program's needs and goals can help provide a diverse funding stream and build the base of supporters for the project.

FRAMEWORK DEVELOPMENT

In developing agency-wide resources for citizen science, USFWS is taking on a leadership role. One interviewee described this as a critical "grease and glue" role for backing and promoting citizen science. This might take the form of building a business case for citizen science within the agency, and equipping staff to justify its use. It could also include advancing citizen science both locally and nationally, recognizing successes and resourcing the implementation of best practices.

BOX 3: USA-NPN/NPS Principles and Objectives for Implementation

"We will need to embrace a multifaceted approach that promotes and facilitates individual creativity and initiative. Operational principles to nurture these relationships are to:

- Communicate regularly and keep the points of contact informed of related activities.
- Use or create products, processes, and methods that are general, facilitate reuse, and that contribute to the broader goals of the partners. Where they exist, use existing standards and follow established guidelines.
- Leverage strengths. Document roles, responsibilities and expectations.

… These opportunistic field activities must be used to develop relationships, generate results and products, and demonstrate success."

-- An excerpt from the 2009 *Strategy for Developing an USA-NPN/NPS Collaboration for Monitoring Plant and Animal Phenology*

This means developing a framework that will provide a level of confidence that citizen science is a worthwhile approach. One element of a framework might be a flow-chart or decision tree, such as was developed for the Scottish Environment Protection Agency (Pocock et al. 2014, see Figure 3 and Appendix F; additional examples in Appendices D-K). Another element might be a values-based template or code of ethics describing how communities and scientists should work together, such as can be seen in the USA-NPN/NPS Collaboration Strategy document (see Box 3, also Pandya 2012, Pollock and Whitelaw 2005).

Recognize up front that citizen science will cost money and require investments. Citizen science is not something to implement or resource because it is "trendy." It is critical to think about and frame the value of citizen science to agency objectives, what the agency's needs and motivations are, and how citizen science can provide a cost effective means of addressing those goals. Deciding how citizen science can be a good fit isn't just a yes or no prospect – there are many different kinds of citizen science with nuanced advantages and strategies. Clearly articulating both goals and values will help shape the framework and identify the ways citizen science can play a productive role in advancing agency work.

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LIST OF APPENDICES

Appendix A: Experts consulted for the Independent Science Review

Owen Boyle
Chief, Species Management Section
Wisconsin Department of Natural Resources
Wisconsin Citizen-based Monitoring Network

Maria Fernandez-Gimenez
Professor, Forest Rangeland and Stewardship
Colorado State University
Mongolian Rangelands & Resilience Project

Muki Haklay
Professor, Geographical Information Science
University College London (UK)
Extreme Citizen Science, Citizen CyberLab

Greg Newman
Research Scientist, Natural Resource Ecology Lab
Colorado State University
CitSci.org

Rajul Pandya
Program Director
American Geophysical Union
Thriving Earth Exchange

Michael Pocock
Ecologist, Biological Records Centre
Centre for Ecology and Hydrology (UK)
SEPA Report, Conker Tree Science

Kris Stepenuck
Program Director
University of Wisconsin, Madison – Extension
Water Action Volunteers, Vol Mon Network

Julie Vastine
Program Director
Dickinson College
ALLARM

Sarah Weston
Program Coordinator, Environmental Studies
Saint Mary's University (Halifax, Nova Scotia)
CURA H2O

Jake Weltzin
Executive Director, USA-NPN
US Geological Survey
USA-National Phenology Network

Graham Whitelaw
Associate Professor, Environmental Studies
Queens University (Kingston, Ontario)
Canadian Community Monitoring Network

Appendix B: Key resources for citizen science design and use

General, and handbooks

- UK-EOF's Guide to Citizen Science
- Choosing and Using Citizen Science
- US EPA Volunteer Water Monitoring: A Guide for State Managers
- USAwaterquality.org/volunteer
- CitizenScience.org Toolkit
- Federal Crowdsourcing and Citizen Science Toolkit

Dealing with data

- EPA Resources on Quality Assurance Project Plans
- Data Management Guide for Public Participation in Scientific Research
- Data Policies for Public Participation in Scientific Research: A Primer

Working with communities

- Promising Practices for Equity, Diversity, and Inclusion
- Broadening Participation in Biological Monitoring: Guidelines for Scientists and Managers
- Community-based Monitoring, Reporting and Verification Know-how

Design and evaluation

- User's Guide for Evaluating Learning Outcomes from Citizen Science
- Using Results Chains to Improve Strategy Effectiveness. An Foundations of Success How-To Guide

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Appendix D: Bonney et al. (2009) citizen science design model

Steps for citizen science project development[13]

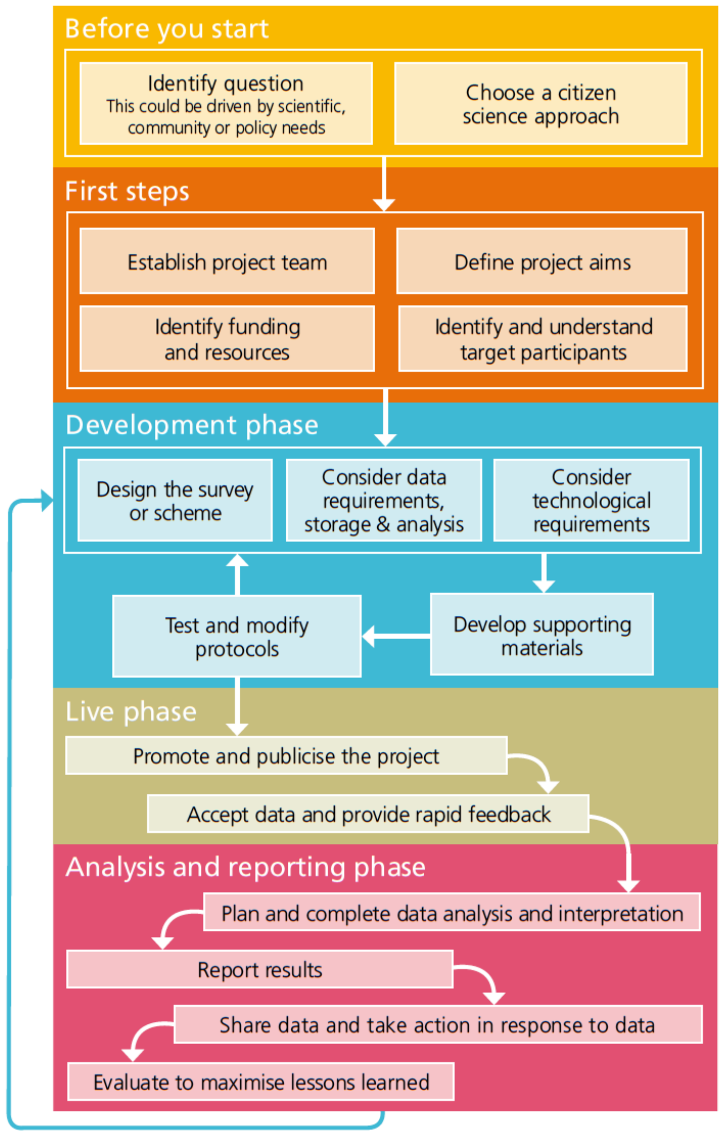
Box 1. Model for developing a citizen science project.

1. Choose a scientific question.
2. Form a scientist/educator/technologist/evaluator team.
3. Develop, test, and refine protocols, data forms, and educational support materials.
4. Recruit participants.
5. Train participants.
6. Accept, edit, and display data.
7. Analyze and interpret data.
8. Disseminate results.
9. Measure outcomes.

13 From Bonney R, Cooper CB, Dickinson J, Kelling S, Phillips T, Rosenberg KV, Shirk J. 2009b. Citizen science: a developing tool for expanding science knowledge and scientific literacy. *BioScience* **59**(11):977-984. These steps form the outline for resources in the original version of the Citizen Science Toolkit, http://www.citizenscience.org/toolkit

Appendix E: Tweddle et al. (2012) design framework

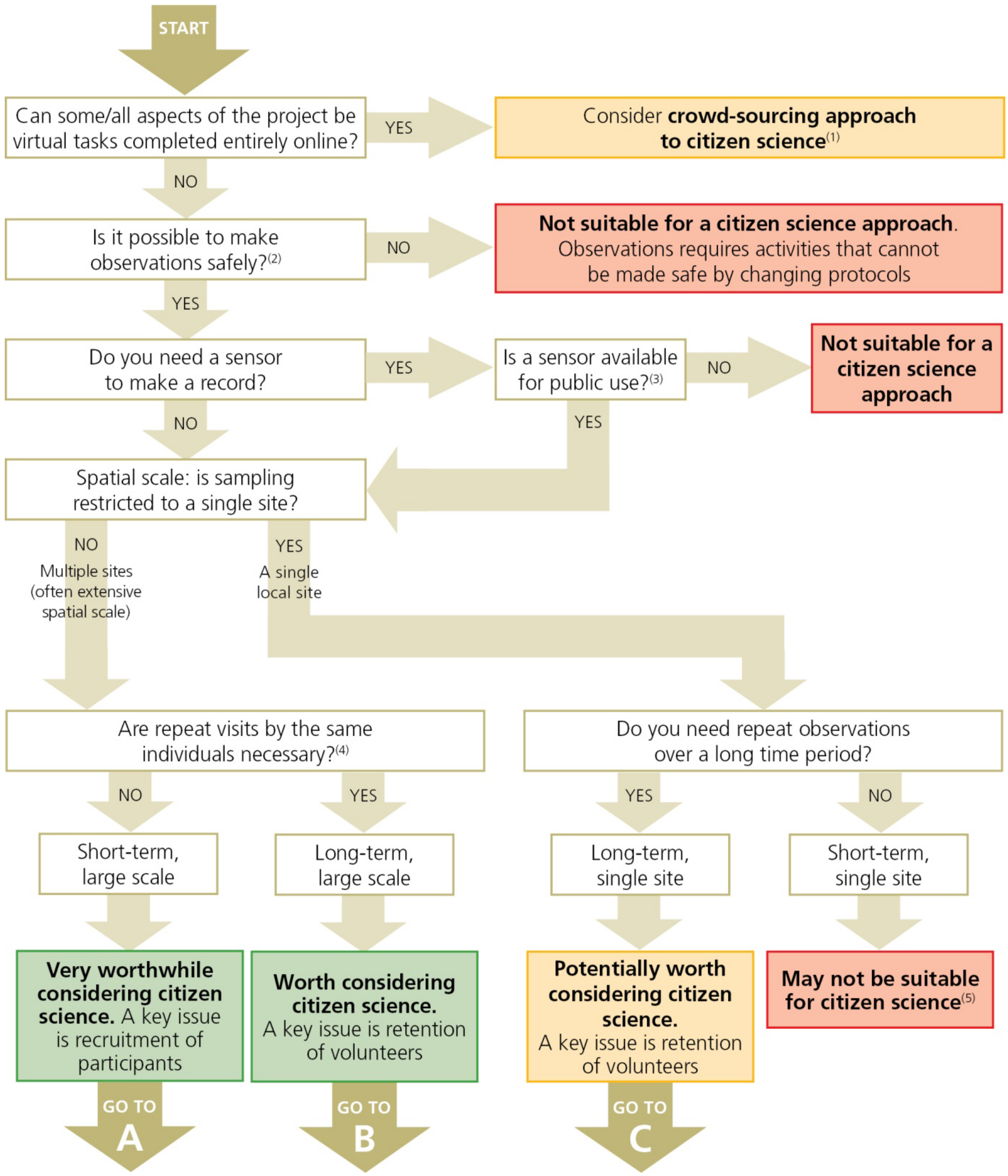
Proposed method for developing, delivering and evaluating a citizen science project[14]



[14] Developed in the UK but not specific to UK projects. Full document citation: 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 NERC Centre for Ecology & Hydrology for UK-EOF. Available online: http://www.ukeof.org.uk

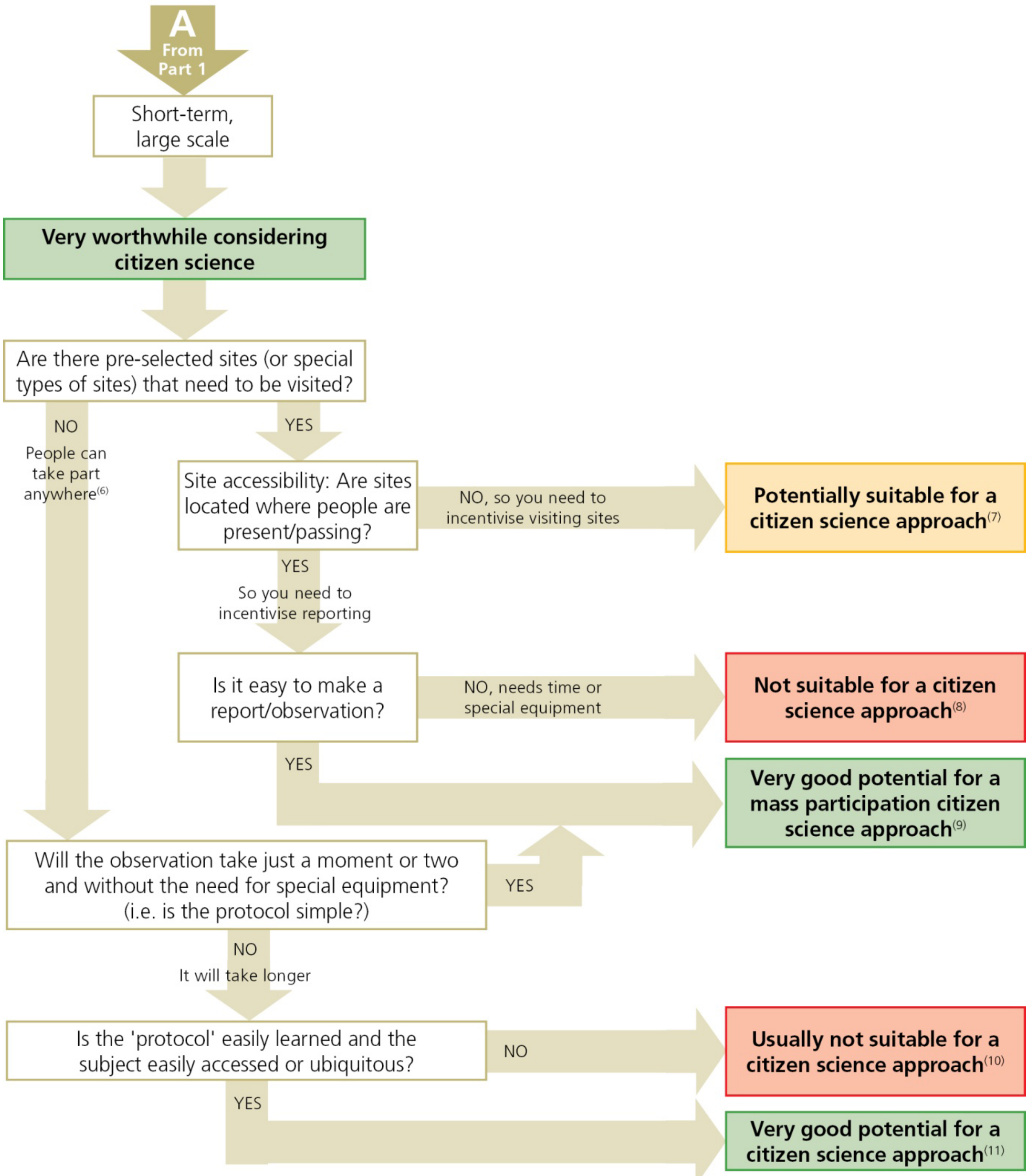
Appendix F: Pocock et al. (2014) decision framework

Part 1 of the decision framework for citizen science [15]

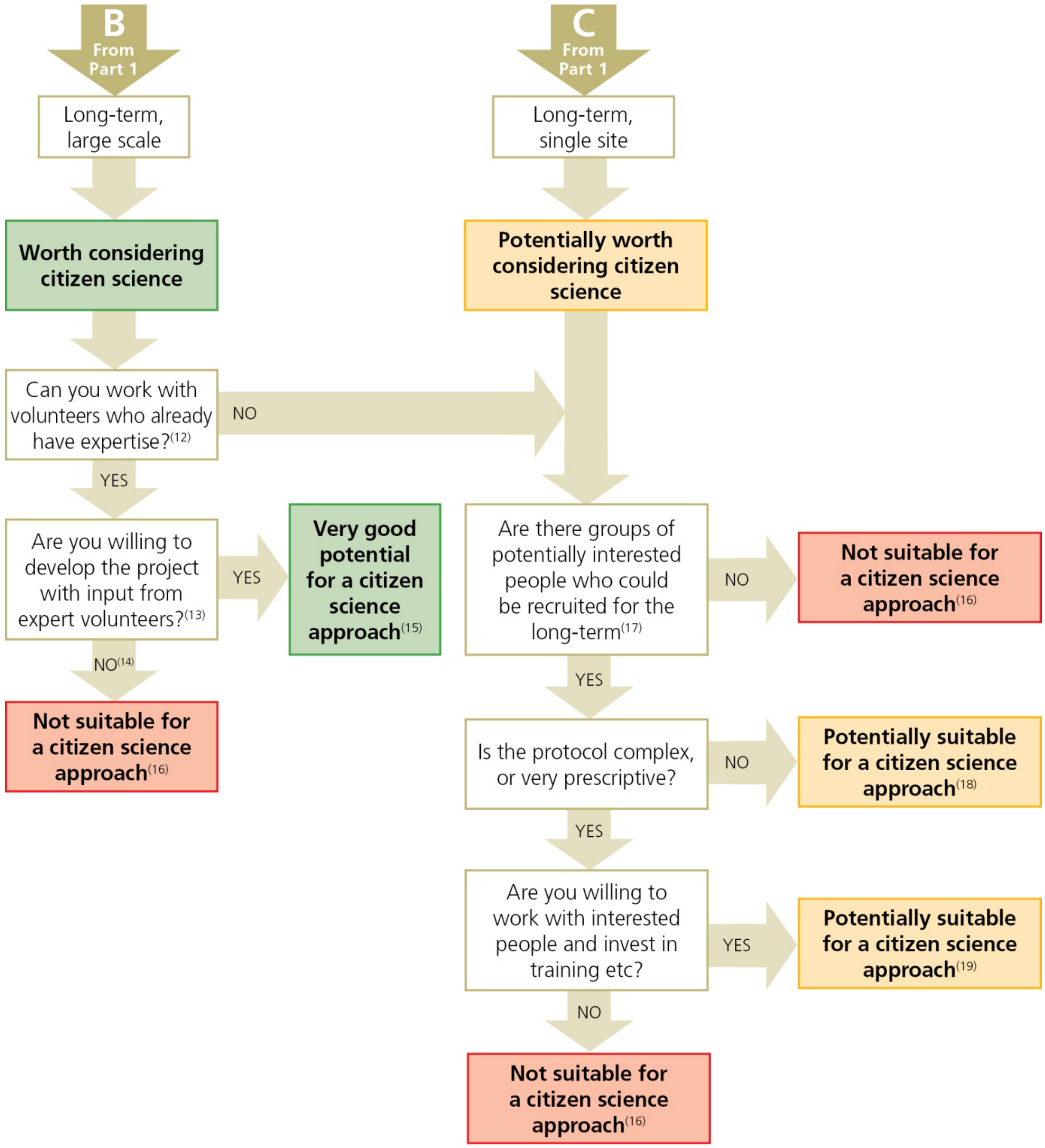


[15] For full background details, including the footnotes from within the image and instructions for interactive use of this framework, see: Pocock MJO, Chapman DS, Sheppard LJ, Roy HE. 2014. A Strategic Framework to Support the Implementation of Citizen Science for Environmental Monitoring. Final Report to Scottish Environmental Protection Agency. Centre for Ecology & Hydrology, Wallingford, Oxfordshire. Online: http://www.ceh.ac.uk/products/publications/understanding-citizen-science.html

Part 2 of the Pocock et al. (2014) decision framework



Part 2 of the Pocock et al. (2014) decision framework (continued)



Appendix G: Haklay (2013) levels of participation

Levels of participation and engagement in citizen science[16]

Level 4 ‘Extreme Citizen Science’

- Collaborative science – problem definition, data collection and analysis

Level 3 ‘Participatory science’

- Participation in problem definition and data collection

Level 2 ‘Distributed Intelligence’

- Citizens as basic interpreters
- Volunteered thinking

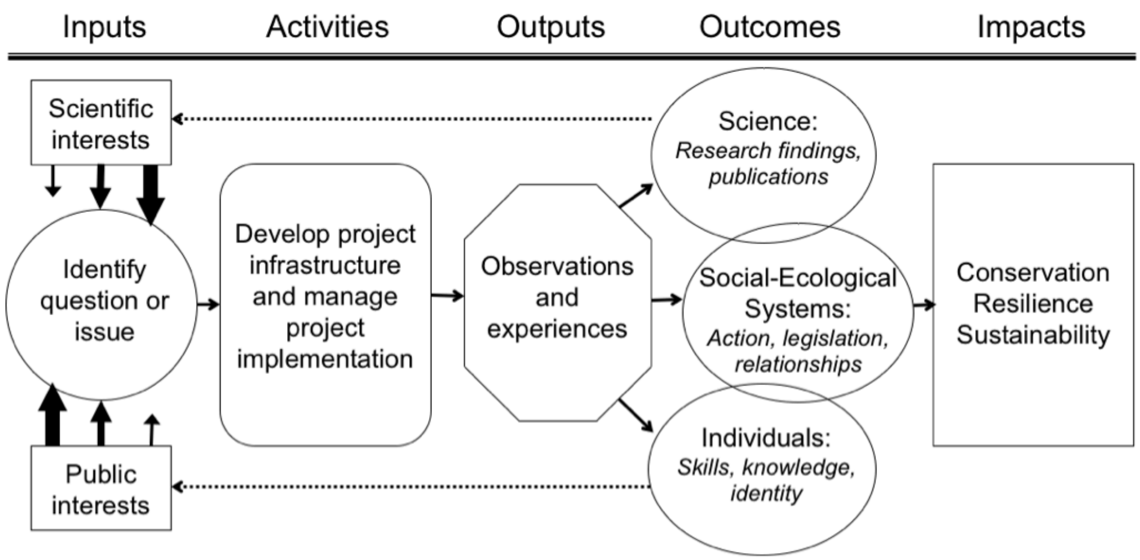
Level 1 ‘Crowdsourcing’

- Citizens as sensors
- Volunteered computing

[16] From Haklay M. 2013. Citizen science and Volunteered Geographic Information: Overview and typology of participation. Chapter 7 in Sui D et al. (eds), *Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice*. Springer, Dordrecht. See also Bonney et al. 2009 and Shirk et al. 2012.

Appendix H: Shirk et al. (2012) framework for project design

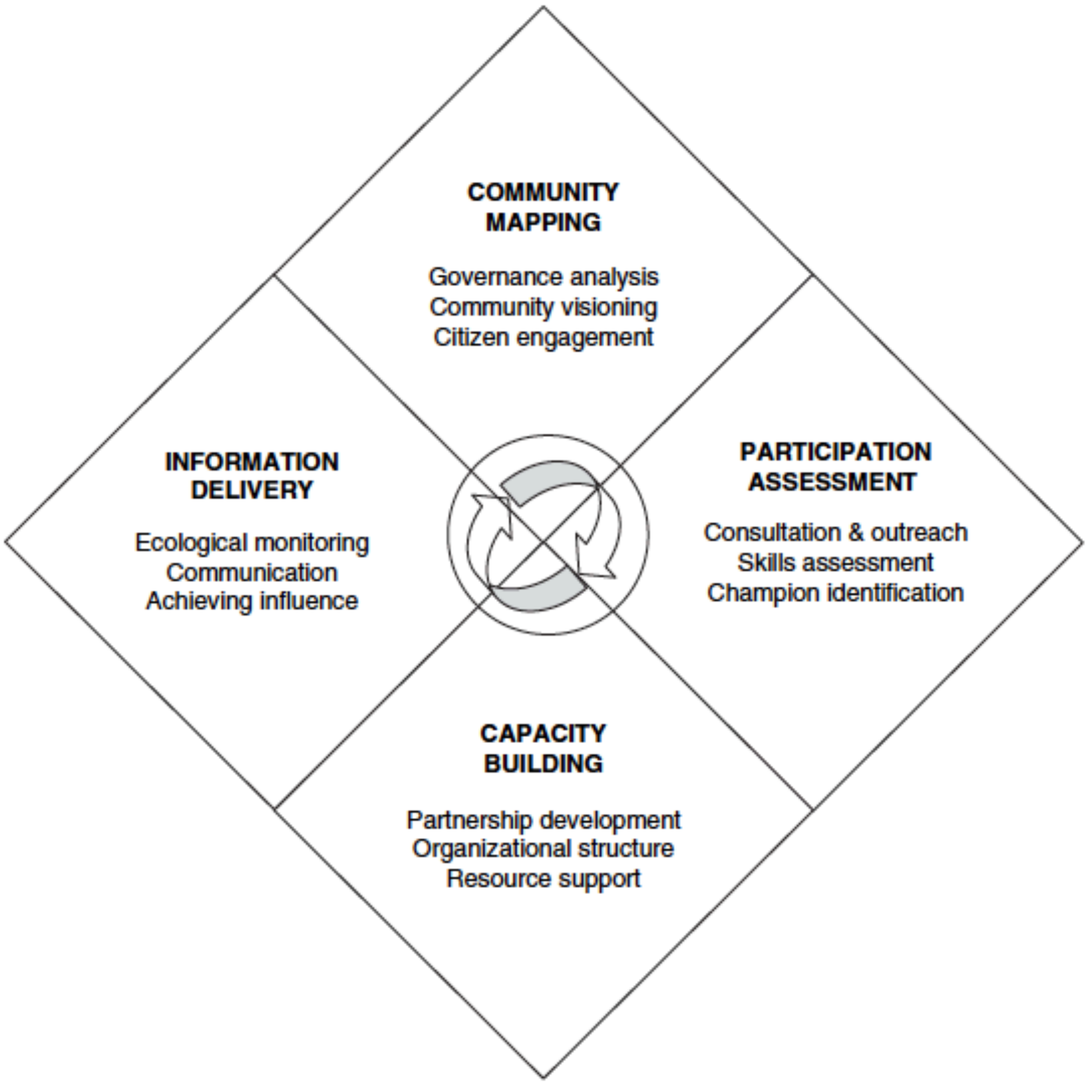
Framework for design of public participation in scientific research initiatives[17]



[17] From Shirk J, Ballard H, Wilderman C, Phillips T, Wiggins A, Jordan R, McCallie E, Minarchek M, Lewenstein B, Krasny M, Bonney R. 2012. Public Participation in Scientific Research: A framework for deliberate design. *Ecology and Society* 17(2): 29.

Appendix I: Pollock and Whitelaw (2005) framework for community-based monitoring

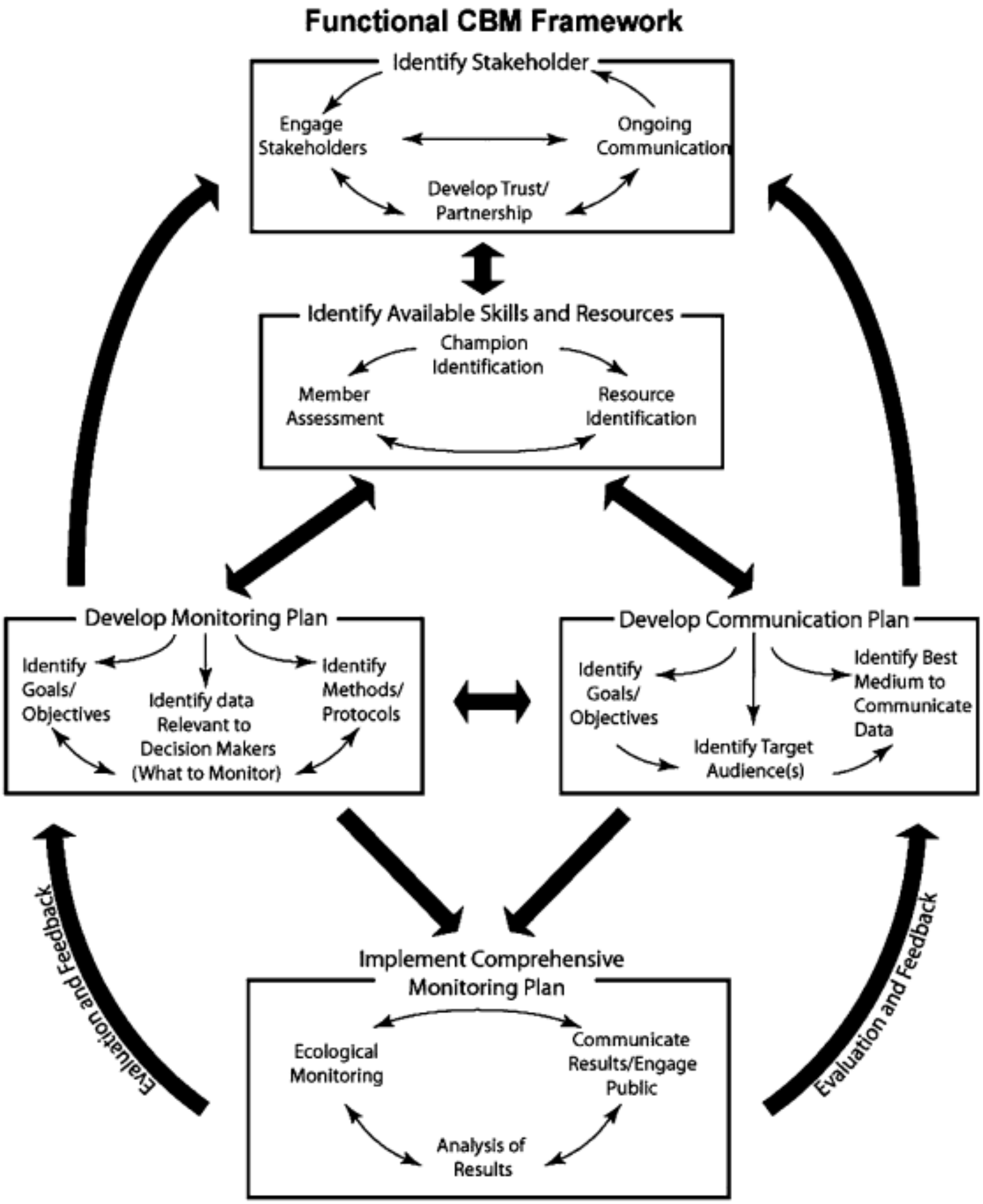
Framework for guiding community-based monitoring in Canada[18]



[18] From Pollock RM, Whitelaw GS. 2005. Community-based monitoring in support of local sustainability. *Local Environment*. 10(3): 211-228. Along with this diagram, Pollock and Whitelaw describe framework components for establishing and implementing community-based monitoring. Components for establishing include governance analysis, consultation and outreach, identification of champions, partnership development, fundraising, and organizational structure. Components for implementing include visioning, membership skills assessment, capacity building, monitoring, achieving influence, and communications planning. Each are described further in their paper.

Appendix J: Conrad and Daoust (2008) framework for community-based environmental monitoring

Framework for guiding community-based monitoring in Canada[19]



[19] From Conrad C, Daoust T. 2008. Community-based monitoring frameworks: Increasing the effectiveness of environmental stewardship. *Environmental Management*. 41: 358-366.

Appendix K: Newman et al. (2011) framework for multi-scale citizen science support

Framework for multi-scale citizen science support[20]

	Aspect	Tension / Continuum	
Scope	Purpose	Perform services	Influence policy
	Domain	Focused	Broad
	Objectives	Create/Act	Learn/Change
	Audience	Lay public	Scientists
	Accessibility	Marginalized	Elite
	Data Quality	Low	High
Scale	Spatial	Local	Global
	Temporal	Short	Long
	Social	Individual	Community
Activities	Research question	Bottom up	Top Down
	Protocol	Pre-existing	Newly Created
	Recruitment	Targeted	Non-Targeted
	Training	Pragmatic	Conceptual
	Volunteer Management	Cursory	Intensive
	Data Management	Loose	Restricted
	Data Dissemination	Local	Global
	Program Evaluation	Formative	Summative
System Approach	Level of Engagement *	Category I	Category V
	Service Provided	Production	Experimental
	Funding Mode	Maintenance	Innovation
	Developer Motivations	User requirements	Design Intents
	Research Model	Development	Research

[20] From Newman G, Graham J, Crall A, Laituri M. 2011. The art and science of multi-scale citizen science support. *Ecological Informatics*, *6*(3), 217-227.