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Conservation outcomes of citizen science

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Highlights

- Different models of citizen science (contributory, collaborative and co-created) can contribute to different types of conservation outcomes.
- Contributory projects, often with large spatial and temporal-scale datasets, may be most likely to contribute to conservation indirectly via research.
- Collaborative and co-created projects, which often include intensive involvement of participants in local conservation issues, may be more likely to contribute directly to site and species management, as well as indirectly via education and capacity building.
- Citizen science project leaders can employ a theory of change approach to design and execute citizen science programmes to achieve conservation outcomes.

Introduction

As environmental problems mount and funding for environmental agencies continues to decline (James, Gaston & Balmford 2001), citizen science is often seen as a cost-effective alternative for agencies that need to routinely gather large amounts of data from diverse locations (e.g., Frost-Nerbonne & Nelson 2004). Citizen science can also have many broader conservation outcomes, including social as well as environmental benefits. Like conservation biology, environment-based citizen science projects have the ultimate goal of advancing understanding of natural systems and protecting biological diversity (Dickinson et al. 2012). A key difference between traditional conservation biology and citizen science is the inclusion of members of the public in collaborative research with professional scientists (see Danielsen et al. 2009 re. indigenous knowledge). The inclusion of the public and the data generated from citizen science can be used by decision-makers to impact policy and natural resource management (McKinley et al. 2015) and thereby impact conservation outcomes. We further argue that this is most effective when citizen science research is closely paired with, and used to inform, environmental stewardship.

In recent decades, there has been a proliferation in the number and variety of citizen science projects with targeted scientific goals aimed at gathering large amounts of data to answer questions at scales unattainable through traditional methods (Bonney et al. 2014). Other projects may also emphasise the impact on volunteers themselves, through explicit educational outcomes that may be cognitive, affective and/or behavioural in nature (Jordan, Ballard & Phillips 2012; Phillips, Bonney & Shirk 2012). The recent dramatic increase in conservation programmes that include citizen scientist-collected data (Theobald et al. 2015) suggests that involving the public in scientific research may also contribute to conservation outcomes.

Although several typologies have been proposed to capture the variety of citizen science projects (e.g., Bonney et al., 'Public Participation', 2009; Danielsen et al. 2009; Shirk et al. 2012; Wiggins et al. 2011), this chapter uses the three-model typology based on participants' level of involvement in the scientific process, first introduced by Bonney et al. ('Public Participation', 2009) and then refined by Shirk et al. (2012). The *contributory* model of citizen science is researcher-driven and focused mostly on large-scale data collection by volunteer participants. It has its roots in disciplines that have historically embraced volunteer involvement such as ornithology (Greenwood 2007), palaeontology (Harnik & Ross 2003) and astronomy (Barstow & Diarra 1997). *Collaborative* projects typically originate with researchers but may include input from participants in multiple phases of the scientific process, such as designing data collection methods and analysing data. This model has its roots in volunteer monitoring, particularly water quality projects in which sharing data with the wider community has the potential to affect local issues (Whitelaw et al. 2003). *Co-created* projects involve participants in all aspects of the scientific process including defining research questions, interpreting data and disseminating findings (see also Haklay; Novak et al., both in this volume). These projects have their origin in participatory action research or community science initiatives, often aimed at addressing public health or environmental justice issues (Fernandez-Gimenez, Ballard & Sturtevant 2008). Broadly speaking, none of these three models is better or worse than the others, but they may vary in the ways in which they contribute to conservation because they differ in numbers of participants, intensity of time and commitment required by participants, and locus of control in terms of who is setting the research agenda.

Defining conservation outcomes for citizen science

Despite the recent surge in citizen science projects globally, the contributions that all three models of citizen science projects can make to conservation have only recently begun to be examined (Conrad & Hilchey 2011; Ballard et al. 2017; Sullivan et al. 2017). Conservation biology as a field also suffers from a relative lack of such evidence of impacts. According to Margoluis et al. (2013), one reason for the lack of evidence is that conservation initiatives are often chosen based on assumptions of what might work rather than on proven success in similar contexts. Further, the efficacy of conservation biology initiatives is not often measured, and when it is, the processes for documenting and measuring impact are seldom shared with other conservation organisations (Margoluis et al. 2013). As such, there is significant scope for the field of citizen science to add to the evidence base for successful and unsuccessful approaches in conservation, and for conservation research to inform citizen science practice (see Kieslinger et al. in this volume for more on evaluation). In response to the need for conservation organisations to better evaluate the conservation impacts of their work (Miller et al. 2004; Spooner et al. 2015), in 2008 the Cambridge Conservation Forum (CCF) developed a conceptual framework to enable organisations to systematically evaluate the effectiveness of their conservation activities (Kapos et al. 2008). This framework was based on an extensive review of current conservation research and the input of 36 conservation organisations. The CCF identified seven categories of activity that lead to targeted improvements in the status of species, ecosystems or landscapes. Two categories of activity have a direct impact on the conservation target – species management and site management – while five influence conservation indirectly – research, education, policy, livelihood and capacity building.

Ballard et al. (2017) adapted the CCF framework to examine natural history museum (NHM)–led citizen science programmes at three NHMs, and found that 59 per cent of programmes contributed towards at least one of the conservation outcomes identified by the CCF (see also Sforzi et al. in this volume on museums and citizen science). In that study, long-term monitoring programmes and those focused on a single site or small geographic area contributed most frequently to conservation outcomes. Sullivan et al. (2017) also modified the CCF framework to document the ways in which eBird data, a project in which users record their own bird observations, were being used in support of conservation science and action. This chapter similarly applies the CCF framework to citizen science programmes that represent the three models described above, to examine whether, and how, each model may be more or less likely to lead to conservation outcomes. This strengths analysis helps to identify the most effective features of each model with regards to conservation outcomes, which could potentially be applied to the others. In line with Ballard et al. (2017), the analysis combines species management and site management into a single category for the purposes of this discussion. Importantly, the programmes analysed here have a variety of goals in addition to conservation; conversely, not all conservation activities can or should be expected of them.

This chapter examines three case studies, one for each of the project models, looking first at the evidence of the conservation outcomes as defined in table 18.1, which has been adapted from the CCF framework (Kapos et al. 2008). It then examines these outcomes for each of the three models to consider how citizen science can leverage the strengths of different types of projects to influence conservation outcomes. This is achieved by looking specifically at the relative extent of a project's outreach; spatial and temporal data coverage; useful data and peer-review publications; contributions to knowledge of global systems; leveraging of, and contributions to, local ecological knowledge; adaptive management and social capital; and contributions to conflict resolution and policy and advocacy.

Table 18.1 Definitions of conservation activities (adapted from Kapos et al. [2008] and Ballard et al. [2017]).

Conservation activity type	Definition and examples
Direct contributions to conservation outcomes	
Species and site management	Managing species and populations (e.g., captive breeding); and managing sites, habitats, landscapes and ecosystems.
Indirect contributions to conservation outcomes	
Research	Research aimed at improving the information base on which conservation decisions are made (e.g., surveys, inventories, monitoring and mapping).
Education	Education and awareness-raising to improve understanding and influence people's behaviour (e.g., campaigns, lobbying and educational programmes).
Policy	Developing, adopting or implementing policy or legislation (e.g., management plans, trade regulations and actions to enforce conservation goals).
Livelihoods	Enhancing and/or providing alternative livelihoods to improve the well-being of people impacting species/habitats of conservation interest, (e.g., through sustainable resource management, income-generating activities, etc.).
Capacity building	Actions to enhance specific skills among those directly involved in conservation.

Comparative citizen science contributions to conservation

This section presents three examples of citizen science projects (table 18.2) selected because (1) they serve as representative examples from around the world of the three models of citizen science defined above, and (2) they are long-standing programmes so evidence of their contributions to conservation are readily available on the internet and in peer-reviewed literature. It is important to note, however, that these projects are just one example of each of the three models, and that the structures, goals and topical foci of other projects in each model can vary widely. For example, contributory projects are typically focused on a specific taxonomic group

Table 18.2 Summary of the three examples

Project title	Model	Location and scope	Conservation activity type (from Kapos et al. 2008)
GBIF: Global Biodiversity Information Facility (see box 18.1) https://www.gbif.org	Contributory	Global	Research
Hudson River Eel Project (EELS) (see box 18.2) http://www.dec.ny.gov/lands/49580.html	Collaborative	Regional (New York, US)	Site and species management, education, capacity building
Community group–led ecological restoration (see box 18.3) http://www.landcare.org.nz/Regional-Focus/Manawatu-Whanganui-Office/Citizen-Science-Meets-Environmental-Restoration	Co-created	National (New Zealand)	Site and species management, education, capacity building

Box 18.1. GBIF: Global Biodiversity Information Facility – contributory citizen science

Citizen science contributions to GBIF-mediated data

Kyle Copas, GBIF Secretariat, Denmark

GBIF, the Global Biodiversity Information Facility (https://www.gbif.org), is an open-data research infrastructure for biodiversity information funded by the world's governments. The GBIF network supports and enhances capacity for providing free and open access biodiversity data by sharing common standards and data formats, open-source software and peer-to-peer professional development. As such, it fits the contributory model of citizen science.

Establishing direct connections between GBIF and the CCF framework can prove difficult, not least because 'raw' species data mediated by GBIF are rarely cited explicitly in policy and on-the-ground conservation management and protection, even if note-worthy exceptions do occur (e.g., Secretariat of the Convention on

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Biological Diversity 2014; US Fish and Wildlife Service 2014; US National Oceanic and Atmospheric Administration 2014). However, substantive uses of GBIF-mediated data appear in peer-reviewed papers at a rate of more than one a day, signalling that GBIF produces clear indirect conservation outcomes through facilitating research.

An example of GBIF contributions to research is its role in GEOBON (Group on Earth Observations Biodiversity Observations Network). GEOBON has developed its concept of Essential Biodiversity Variables (EBVs), a minimum set of measurements needed to capture and track the major dimensions of biodiversity change over time (Pereira et al. 2013). In late 2015, the GBIF Secretariat sought to understand how and where citizen science already contributes to EBVs, and the global agendas they support, by reviewing citizen science contributions to species occurrence datasets available through GBIF.org.

The results (Chandler et al. 2017) showed that species occurrence datasets gathered largely or entirely by citizen scientists contributed up to 349 million of the 640 million species occurrence records available through GBIF.org, as of 1 March 2016. The contributions are uneven across taxa, although citizen science programmes account for 70 per cent of all GBIF-mediated records for animals and 87 per cent for birds (largely due to eBird data). Citizen science contributions also show biases at regional and national scales (table 18.3). However, placed in the context of the research team's broader finding that fewer than 10 per cent of all relevant citizen science programmes contribute data to GBIF, improving publishing tools and incentives for citizen science programmes could do much to close the large worldwide gap in data sharing.

Table 18.3 Geographical distribution of occurrences contributed to GBIF by regional location of occurrence

Continent	Number of occurrence records	Per cent of total citizen science contributions
North America	202,269,978	58.0 per cent
Europe	119,671,494	34.2 per cent
Oceania	17,987,545	5.2 per cent
Central and South America	4,327,079	1.2 per cent
Asia	2,727,302	0.8 per cent
Africa	1,785,960	0.5 per cent

Box 18.2. Hudson River Estuary Eel Project – collaborative citizen science

Collaboration between a state agency, local residents and schools

Chris Bowser, New York State Dept. of Environmental Conservation, US

The Hudson River Estuary Eel Project (EELS, http://www.dec.ny.gov/lands/49580.html) began in 2008 at two sites on the Hudson River, and as of 2017 had expanded to a dozen sites with over 750 volunteers. American eels hatch in the Atlantic Ocean and drift/swim to the North American East Coast. Many continue their journey upstream to fresh water to grow into adults before returning to the ocean years later to reproduce. This species is in decline in much of its range, and this project provides crucial baseline data about the young eel population in the Hudson River. Volunteers coordinated by the New York State Department of Environmental Conservation (NYDEC) catch and count thousands of juvenile American eels (*Anguilla rostrata*), known as 'glass eels' for their transparent appearance at this lifecycle stage, each year and release them above dams or other barriers to their migration.

As a catch and release programme, the project also restores the migration patterns of thousands of eels by moving eels upriver from a dam/obstruction. The EELS primarily involves teachers and river-based organisations who use the experience of wading through streams with nets and other equipment to provide local high school students with authentic science field skills, often over many weeks. This is a collaborative citizen science project because, at some sites, participants have taken on leadership roles to collaborate with the project coordinator from NYDEC over the course of the project's evolution and expansion. In some cases, this involved participants modifying aspects of the protocol that were then adopted as new methods across sites, and in other cases community-based organisations and teachers approached the project coordinator to develop and implement a site in their own stretch of the river.

The contributions to conservation education are documented by the teachers integrating the content into their curriculum to help students learn about the biology and ecology of this unique species and the Hudson River ecosystem. The contributions to site and

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species management, then, come from the integrated nature of the project, where both monitoring and stewardship takes place in tandem throughout the project. The involvement of the local community and young people, who adopt their own EELS sites and some of whom participate for multiple years, also indicates a contribution to conservation capacity building as defined by Kapos et al. (2008). The project has documented an overall increase in the number of eels caught over the monitoring period, increasing from an average of 17.5 eels caught per day across all sites in 2008 to 215 eels in 2016; this may indicate increasing populations, though more information is needed (Bowser 2016; see table 18.4). In addition to using nets for catch and release each spring, volunteers and project co-ordinators have collaborated to develop low-cost eel ladders at several sites, which are made from large plastic tubing and netting that allow eels to climb the ladder into buckets where they are counted and released up stream during summer months.

Table 18.4 Total eels caught and eels caught per day as a catch per unit effort (CPUE) combined for all sampling sites in that year

Year	Total YOY glass eels	CPUE YOY glass eels	Total elvers	CPUE elvers	Total eels caught	CPUE Total eels caught
2008	2,388	16.6	181	1.8	2,569	17.5
2009	7,740	34.8	430	1.7	8,170	36.5
2010	10,603	21.6	1,411	3.2	12,014	24.8
2011	6,964	16.1	1301	3.4	8,265	19.5
2012	85,166	128.9	1,432	1.9	86,598	130.8
2013	103,123	188.3	1,647	2.3	104,770	190.6
2014	49,760	124.9	683	1.5	50,443	126.5
2015	48,158	114.6	1,298	3.3	49,456	117.8
2016	142,770	221.5	2,383	3.6	145,153	215.1
Total	**456,672**		**10,766**		**467,438**	
Average		**95.3**		**2.5**		**97.7**

Source: Bowser 2016

Note: In this study, eels are separated into two age classes: young of year (YOY) glass eels and elvers. ‘Glass eels’ are just entering the Hudson River system in the spring of the sampling year (which includes recently pigmented eels in late spring), and ‘elvers’ are fully pigmented eels that have been in the Hudson River system for at least a year.

Fig. 18.1 Local students checking eel nets for a daily survey of glass eels in a local stream. (Source: Hudson River Eel Project)

Box 18.3. Community group–led ecological restoration network – co-created citizen science

Grassroots citizen science in New Zealand: Quantifying community-led conservation gains

Monica A. Peters (Hamilton, NZ) and Ngaire Tyson (New Zealand Landcare Trust)

Prior to the thirteenth century, New Zealand's unique suite of flora, fauna and fungi had evolved in isolation with no land mammals, other than two species of diminutive bat. A history of land use change and the introduction of new biota have had disastrous effects on native ecosystems. In response to ongoing threats to indigenous biodiversity and continued habitat decline, a recent study investigated community group–led monitoring and ecological restoration in New Zealand (Peters, Eames & Hamilton 2015). Some 540 self-mobilising groups operate largely independently of one another, but identify as a part of a large, loosely defined network of community-based restoration practitioners, that contribute both to active restoration and monitoring through citizen science approaches (see https://www.naturespace.org.nz/groups).

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Contributions to site and species management for conservation have been documented at the community group level: Major biodiversity gains have been achieved through sustained invasive species control or eradication; revegetating cleared land and riparian margins with native species; restoring wetland hydrology; and translocating threatened species to their former habitats. A recent study identified that nearly half of the groups (49 per cent, $n=282$) carried out their own monitoring or grassroots citizen science, primarily to determine their restoration management outputs (e.g., number of rodents trapped), rather than the conservation outcomes of their activities (e.g., increases in desirable avifauna species resulting from predator control) (Peters et al. 2016). Contributions to conservation research cannot be substantiated currently because monitoring results are not widely used beyond the scope of the groups' own projects, owing to differences in data formatting, monitoring methods and objectives, and questions around data quality (Peters, Eames & Hamilton 2015). For this reason, quantifying community conservation efforts nationally through groups' own data is challenging and needs to be addressed. The government's ambitious 'Predator Free 2050' plan to rid New Zealand of key introduced species may support greater co-ordination between groups and promote more strategic data collection in the future.

Based on this co-created model, key recommendations for countries with dispersed community-led restoration initiatives include the following:

1) Providing greater support from agencies/NGOs and funders to promote and support strategic intra-group co-ordination;
2) Co-funding contractors to work across groups to enable consistent data collection; and
3) Using a partnership approach from the outset to design monitoring programmes that meet the information needs of both groups and partners (e.g., a guide is currently being produced for the Auckland Council to ensure consistency when council staff work with community-based organisations).

or geographic region, (i.e., eBird [ebird.org], the Coastal Observation and Seabird Survey Team [COASST, https://depts.washington.edu/coasst/], and the Monarch Larvae Monitoring Project [https://mlmp.org/]), in which participants affiliate with, and contribute to, a specific research or monitoring question. In the example in box 18.1, however, the Global Biodiversity Information Facility (GBIF) is a global and taxonomically inclusive platform to which many citizen science projects contribute. Therefore, these three projects simply serve as illustrative examples. Each project is described in a separate box as listed in table 18.2.

These examples highlight several important points for citizen science projects that wish to contribute to conservation.

1. It is possible to evaluate and document the ways a citizen science project contributes to the key conservation activities outlined by Kapos et al. (2008), but evidence must be deliberately collected. This evidence is often difficult to collect and often requires additional funding beyond project implementation alone, which is also a challenge for the field of conservation more broadly, as noted above. The lack of evidence of conservation impacts in some of these citizen science examples may not indicate a lack of impact but that projects must devote greater resources to evaluating their own activities and outcomes.
2. Citizen science projects may not only indirectly impact conservation through research and education, but also directly through site and species management. Both the EELS and the New Zealand community-based restoration projects closely integrate stewardship with citizen science activities, through the catch and release of juvenile eels, or invasive species controls and revegetation, respectively. Specifically, volunteers in both projects are trained and then implement the scientific monitoring as essential and complementary to the direct stewardship activities that impact habitats and species. Other citizen science projects are finding success in this approach, for example in coastal eelgrass systems where volunteers plant eelgrass and monitor it repeatedly in Maine, US. (Disney et al. 2017), or when volunteers assess and weigh marine debris on beaches and then dispose of it (Thiel et al. 2017). With respect to education outcomes, volunteers can gain awareness of the need for both scientific monitoring and stewardship actions for enhancing long-term conservation of species and habitats and making evidence-based management decisions. Importantly, scientists and land managers not only benefit from the restoration work on the ground

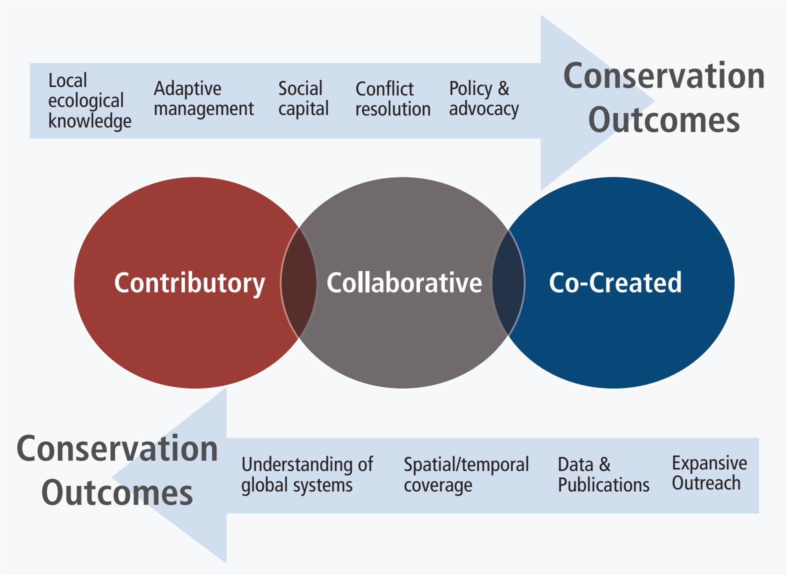

Fig. 18.2 Relative strengths of three models

but also the regularly collected data they need to manage it effectively. Combining activities in this way means that citizen science projects can achieve both short- and longer-term impacts for conservation while fostering volunteers' passion and commitment for conservation.

3. Some models may be better suited for particular activities that contribute to conservation (see figure 18.2). For example, *collaborative and co-created* projects that facilitate in-depth interaction and shared practice among participants and between scientists and participants tend to allow participants to gain a deeper awareness of environmental and community-based advocacy issues, and often increase trust between scientists and the public (see also Fernandez-Gimenez, Ballard & Sturtevant 2008). The local and regional scale many of these projects operate in also facilitates the inclusion of local expertise and may promote enhanced social capital, adaptive management opportunities, improved conflict resolution and policy and advocacy initiatives (Fernandez-Gimenez, Ballard & Sturtevant 2008). At the other end of the spectrum, contributory projects with larger participant numbers and large spatial and temporal coverage tend to produce data that is highly utilised and disseminated in peer-reviewed publications (see also Sullivan et al. 2017).

Large databases can accommodate a proportion of error while remaining high quality, which in turn improves knowledge of global systems.

Improving citizen science contributions to conservation

This chapter provides examples of how engaging the public in conservation research can contribute to desired outcomes but questions remain about (1) the specific pathways by which conservation goals can be reached in citizen science and (2) which models of citizen science best support or facilitate each of these pathways. Margoluis et al. (2013) suggest the use of 'results chains' to describe how the implementation of project activities and assumptions about how projects operate link to relevant short- and long-term impacts. Citizen science projects could apply this tool alongside the notion of 'theory of change' (Weiss 1995), a planning and evaluation tool increasingly used in conservation biology, to articulate conservation pathways in citizen science. Theory of change has its origins in the field of evaluation, and is a graphical representation of the process by which clearly identified goals are reached (Weiss 1995). Theory of change provides explanatory linkages between project activities and outcomes, usually with 'if . . . then' statements, and seeks to explain how, and why, the desired change is expected. Developing a theory of change requires the articulation of assumptions about why certain activities will lead to intermediate outcomes as well as the identification of indicators of success for measuring whether intermediate outcomes were achieved (see the Center for Theory of Change: http://www.theoryofchange.org). Results chains then include evidence of results added to the theory of change such that evidence of the specific pathways by which a citizen science project leads to one or more conservation outcomes can be properly examined. This would allow the field to identify successful strategies for documenting and even measuring intermediate, but necessary, steps or outcomes that are important for achieving ultimate conservation impacts. In fact, systematically and rigorously analysing the evidence of intermediary results from citizen science projects following Margoluis et al. (2013) could also provide cautionary scenarios for the potential misuse of, or over-emphasis on, citizen science in achieving conservation outcomes. While documenting the results chains for the specific citizen science projects in this chapter is beyond the scope of the chapter, this is a way forward for the field to become more critical of the way citizen science may, or may not, be contributing to conservation outcomes.

Conclusions

Conservation biology at its core seeks to directly impact biodiversity through site and species restoration and preservation (Kapos et al. 2008). One of the main lessons from examining a spectrum of citizen science programmes is that citizen science, conversely, tends to affect conservation *indirectly* through the application of research findings, education of stakeholders, policy changes and individual and community-level actions. Direct contributions may primarily occur when citizen science is coupled with related restoration and stewardship activities. Although the mechanisms for how these ultimate conservation outcomes are reached have not been well-studied, these indirect pathways may have a significant impact on conservation goals. These case studies demonstrate the need for better tracking of the onward use of citizen science data (and indeed any research data) for environmental conservation purposes, to ensure that citizen science can be targeted where it is most effective or most needed, and that its contribution to conservation is recognised. While evidence for the conservation outcomes of citizen science is still lacking in many cases, more projects are beginning to evaluate conservation outcomes, which will help build a better understanding of what structures and approaches produce specific intended conservation outcomes. Most importantly, this chapter has highlighted the ways each model of citizen science may support different types of conservation outcomes. Project designers can therefore take into account the strengths and structures from each model to design for the conservation outcomes they seek, as well as explicitly state their theory of change and document evidence for the intermediary results throughout their projects.