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Learning from successful long-term citizen science programs

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ABSTRACT

Citizen science is increasingly recognised as an important, indeed necessary, contribution to environmental research and policy, as well as for fostering stronger relationships between scientists and the broader community. Well-established citizen science projects offer valuable insights by virtue of the long-term contribution of volunteers to sustained research and monitoring activities. Here we draw on two of Australia's longest running citizen science projects, Waterwatch and the Australian Shorebird Monitoring Program (formerly Shorebirds 2020), to argue that such projects reflect successful citizen science in terms of their program persistence, reputation and impact. This success has been enabled by (1) developing a clear vision; (2) effective knowledge management; (3) relationship building; (4) meaningful volunteer engagement; and (5) a capacity to adapt to change. We recommend that new and emerging projects embed these principles in their program development, particularly those aiming to generate longitudinal datasets while building motivated, informed and connected communities.

Keywords: community-based monitoring, migratory shorebirds, natural resource management, river health, Shorebirds 2020, technology, water quality, Waterwatch.

Introduction

Citizen science is the practice of involving the public in scientific investigations, and is now widely adopted by government agencies, research institutions and community-based organisations (Vohland *et al.* 2021). Several societal changes have driven this recent uptake, including rapid advances in information and communication technology (ICT), funding constraints in environmental science and natural resource management, and a national policy focus on improving STEM (science, technology, engineering and mathematics) capability. These changes have increased opportunities for the public to actively participate in science and environmental governance.

Citizen science is not a new practice, with many ongoing projects predating this recent popularity (Vetter 2011; Miller-Rushing *et al.* 2012). However, the recent explosion in citizen science has focused more attention on quality in terms of design and implementation, and the need to clearly articulate the purpose of a project (Stevens *et al.* 2019). Funding and volunteer efforts are being committed to a greater number of project life cycles and programs are shortening, while recognition of their contribution to science and society is increasing. Therefore, it is important to understand and apply lessons from existing programs to benefit and sustain emerging efforts. Ongoing, historic programs enrich the citizen science landscape, one that is increasingly characterised by shorter-term research goals, more temporary volunteer engagement, and more heavily technology-mediated participation. Short-term citizen science projects and episodic volunteering may offer a different set of advantages (Shirk *et al.* 2012; Cnaan *et al.* 2021), dependent on their objectives (Table 1). However, they can have disadvantages where program objectives include measuring environmental change (often requiring longitudinal data), sustaining volunteer participation and project persistence.

From our perspective, long-term citizen science projects provide important lessons on key contemporary issues for new and emerging projects, including for knowledge management and uptake, volunteer recruitment and retention, coordination and

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Table 1. Benefits and limitations of short- versus long-term citizen science projects.

	Benefits	Limitations
Long-term projects	Identifying and forecasting trends in environmental condition	Maintaining consistency of data records
	Cultivating a sense of community and a common vision shared by all participants	Time and resource-intensive
	Opportunities to share project findings and refine project protocols	Volunteer burnout
	Greater likelihood to influence decision-making	Sustaining volunteer and partner commitment to project activities
	Developing strong sense of stewardship and appreciation of ecosystem complexity	Potential risk of 'monitoring for the sake of monitoring'
	Opportunities for relationship building across varied stakeholder groups	
Short-term projects	Greater likelihood for high data precision and accuracy of data	Low potential impact on decision-making
	Suited to co-created forms of citizen science	Fewer opportunities for building trust between volunteers, researchers and agencies
	Accessible for volunteers with diverse motivations, capabilities and capacities	Large pool of participants necessary to collect large amounts of data
	Can extend and complement existing standardised monitoring	Limited capacity to understand longer-term ecological impacts and trends
		Lower potential to affect changes in environmental literacy and stewardship
		Initial volunteer recruitment difficult

partnership building. In this article we describe two of Australia's longest running citizen science projects, Waterwatch and the Australian Shorebird Monitoring Program (ASMP), to characterise and highlight key factors that have enabled their persistence, reputation and impact (Boxes 1 and 2). Both projects are decades old and represent typical approaches to citizen science in water quality and ornithological monitoring, respectively. Despite some contextual differences, both programs display common characteristics enabling their long-term contributions to science, society and policy that can serve as a useful model for new program development.

Valuing long-term citizen science

We are currently witnessing a meteoric rise in the number of citizen science projects across the world. They operate in diverse social and environmental contexts but are broadly underpinned by goals to advance scientific research while promoting public inclusion in the processes of knowledge production. Many newly created projects conform to a particular, dominant model, termed the 'contributory model' (Bonney *et al.* 2009), in which volunteers primarily assist professional scientists or researchers in data collection, often using technology such as mobile devices. These project types are commonly tied to specific and finite research projects and/or engagement initiatives. This type of program runs the risk that, once completed, it loses momentum as project funding ceases, or lacks the capacity to support and maintain ongoing volunteer participation. This may be counter to the original program objectives, which may include longer-term goals. To support sustainability and to maximise the potential of emerging projects, there are insights that can be applied from long-term projects, which have persisted despite these challenges; enabling them to deliver important outcomes for science, environments and communities.

Here, we refer to long-term citizen science as established projects that have operated over more than a decade, conducted long-term research or monitoring, and are committed to and reliant upon sustained volunteer participation. It is these characteristics that, we argue, promote enduring societal and environmental outcomes not easily achieved in short-term projects and temporary volunteer engagements. In this section, we describe three such outcomes that reflect the value of long-term citizen science: (1) understanding environmental change; (2) fostering environmental stewardship; and (3) strengthening societal connections. We draw on examples from Waterwatch (Box 1) and the ASMP (Box 2) to illustrate these values.

Box 1. Waterwatch

Waterwatch was launched in Australia nationally in 1993 and was delivered alongside several other 'Watch' and 'Care' programs focusing on various aspects of the environment, including water quality, biodiversity, coasts, dunes, soils and riparian management (Bonney *et al.* 2020). Throughout its history, Waterwatch has engaged volunteers in a combined process of place-based learning and scientific enquiry around local waterways (Carr 2002).

The program has maintained a sound reputation within government departments for its flexible approach, which has enabled programs to adapt to local environmental contexts. This flexibility has meant projects are able to advance a wide range of science and engagement objectives and be supported by a range of organisations, including state governments, regional catchment management authorities and community-based organisations. In some projects, volunteers have substantial control over the processes and outcomes of their activities, whereas in other cases, Waterwatch is guided by policy supporting the integration of the program's data into government decision-making.

Within the last decade, strategic improvements to Waterwatch have become increasingly important as the program was challenged to justify its value in a shifting political and economic environment. The national Waterwatch office closed in 2007, following a shift in funding from a national to a regional delivery model, which had a significant initial impact on program stability (Thomson 2007). Despite this, the project has remained relatively widespread, but more loosely connected across the country. It has built strong associations within the environmental governance landscape, with these informal networks being one of its key strengths that improve the stability of these endeavours through collaboration, knowledge uptake and provision of additional sources of funding.

The philosophy and overarching goals of Waterwatch have been mostly consistent throughout its development, but the program has nevertheless evolved in several important ways. Most notably, there has been a growing emphasis on improving the scientific rigour and focus of Waterwatch, including efforts to improve data standards and monitoring protocols, align monitoring activities with state and regional government objectives and improve data access and management through technological developments. This evolution has occurred against a backdrop of interest by scientists and land managers who have long viewed Waterwatch as a potential solution to fill knowledge gaps and speed up the detection of environmental change. However, a more implicit aim of these improvements reflected a need to shift perspectives among the scientific community, since Waterwatch has at times been met with scepticism by certain groups of researchers and government factions (Finlayson and Mitchell 1999).

Understanding environmental change

Citizen science projects that involve volunteers in long-term monitoring play an important role in delivering longitudinal data to characterise changes in environmental values over time (McKinley *et al.* 2017; Hansen *et al.* 2019). This benefit serves to address longstanding calls by ecologists and conservation scientists to maintain and expand long-term research and monitoring investigations (Callahan 1984; Franklin 1989). These calls are grounded in a recognition of the relatively slow pace and highly variable nature of ecological processes that drive environmental change. Without the temporal context provided by long-term investigations, it is difficult to track and forecast trends in environmental condition or implement mitigative measures.

Both Waterwatch and the ASMP have well-established protocols and methods for robust, long-term data collection. Both programs complement professional monitoring and their resulting datasets have been used to analyse trends in environmental condition, advance scientific research, and inform policy development. For instance, Waterwatch has demonstrated an ability to inform environmental decision-making throughout the adaptive management cycle and across geographic scales (Bonney *et al.* 2020). In the case of the ASMP, resulting datasets are collected at spatial and temporal scales not achievable with professional monitoring (due to costs of surveying), and have underpinned the development of various environmental policies, including the National Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia 2015).

Beyond scientific data, Waterwatch and the ASMP encourage volunteers to visit the same sites over long periods of time, which further assists in identifying and understanding environmental change. Based on our experiences and observations in these programs, we have noted volunteers growing accustomed to the gradual changes affecting their 'local patch', which can lead to more rapid detection of changes in these areas (McKinley *et al.* 2017). This is increasingly more relevant as funding constraints reduce the ability of professionals to monitor many locations continuously across large spatial scales.

Fostering environmental stewardship

Long-term citizen science encourages positive stewardship attitudes and behaviours in ways that may be more limited in short-term projects. Research indicates that volunteers in citizen science can develop strong connections to place (Haywood 2016), which leads to pro-environmental

Box 2. Australian shorebird monitoring program

Shorebird monitoring was first established in Tasmania by professional volunteers – these were usually scientifically trained individuals who had a strong interest in shorebirds, but worked in industry. Funding came later through the connections of individual volunteers with potential investors, which led to the establishment of the national wader count in the early 1980s. Between 1986 and 2000, the population monitoring program (PMP) was run by volunteers but from 1991 onwards there were no concerted efforts to analyse the accumulating monitoring data.

In 1993, the first national shorebird plan was produced, funded by the World Wide Fund for Nature (Watkins 1993) and in 1995, Environment Australia contracted Peter Driscoll to analyse data from the PMP. Despite these two reports, monitoring lagged into the late 1990s and 2000s largely due to a lack of coordination capacity (Wilson 2001). As Wilson states in his 2001 report on the PMP 'the proper running of the PMP will always be beyond the scope of volunteers'. In mid-2000, national shorebird monitoring was reinvigorated by funding from the Commonwealth government (under the National Heritage Trust (NHT) and Caring for our Country programs) to the Birds Australia (now BirdLife Australia) Shorebirds 2020 project to coordinate the PMP. Along the way various wader study groups have been formed and have contributed participants and data at regional or state scales.

The use of data in scientific publication has constantly lagged behind the data collection, and was continuously highlighted as a major problem (Wilson 2001; Gosbell and Clemens 2006). This has improved since 2010, and a concerted analysis and publication effort done in partnership with universities (initially the University of Queensland and Deakin University, e.g. Studds *et al.* 2017) has ultimately helped drive national policy and legislative change (Commonwealth of Australia 2015).

A new database was developed during the period of Wilson's (2001) report and was the only data management system until the 2010s, when the Birdata system was developed by BirdLife Australia to collect and manage all data generated through the organisation (including shorebird data). This was an important advancement for the program, because it enabled more rapid data entry and verification, which has sped up the process of data handling for analyses. As smart phone use has become commonplace, the data collection app has been a useful training tool in terms of exposing users to the principles of collecting structured data and links to other resources. Finally, the technology has provided a mechanism for improving feedback and attribution through the mapping portal and associated online content.

The contributions of volunteers to shorebird monitoring vary greatly. Some participants are content to be the data collectors and the program hinges on maintaining the goodwill and involvement of these people. However, others contribute through their scientific, administrative, political or artistic backgrounds, and these different types of contribution require different approaches for support, engagement, recognition and attribution.

behaviour (Ramkissoon *et al.* 2012). Volunteer shorebird surveyors are often advocates for environmental protection around proposed developments that are likely to impact important shorebird habitat. For example, shorebird surveyors in Queensland have drawn on decades of continuous shorebird monitoring in objection to a proposed marina development within the Moreton Bay Ramsar site at Toondah Harbour (QWSG 2017). Similarly, volunteers in the Waterwatch program are regularly advocating for improved management of local waterways, and often use their data to support their concerns (Bonney *et al.* 2020).

In both programs, many longstanding participants have become influential advocates for their project, helping to spread environmental messages through the community, linking different groups and organisations and encouraging others to participate. So-called environmental champions (e.g. Mould *et al.* 2020) are reservoirs of knowledge for new volunteers, as well as project coordinators, researchers and government officials. Some shorebird volunteers, together with professionals, actively represent the research and monitoring conducted by the broader volunteer membership in international fora such as the East Asian-Australasian Flyway Partnership (https://www.eaaflyway.net/), which includes delegates of national governments responsible for the conservation of migratory species (Watkins and Russell-French 2017). This level of involvement has been made possible by the decades of participation, collective and purposeful knowledge generation and by virtue of their place-based approach on issues of local interest and concern.

Strengthening societal connections

When connected to issues of local interest and concern, citizen science not only fosters positive stewardship behaviours, but also strengthens connections between a variety of stakeholders across the research and policy landscape. This benefit is especially relevant in the context of environmental governance, where it is important to involve multiple stakeholders in identifying and addressing environmental problems (Newig and Fritsch 2009). As such, the participation of the public and other non-government stakeholders has become a central tenet of contemporary environmental governance. In this context,

the capacity of citizen science to facilitate linkages between governments, universities, industry and community stakeholders is a fundamental, yet often underappreciated, benefit of the practice. However, these relationships take time and trust to develop, a benefit not easily achieved in short-term citizen science projects.

Indeed, the longevity and success of Waterwatch and the ASMP are largely attributable to their capacity to partner with a range of organisations relevant to the investigations and environmental issues in question. For instance, the waterway management-oriented focus of Waterwatch sees the program strongly associated with government agencies at regional and state scales, but also with other non-government and community-based organisations involved in local environmental issues. The research-oriented focus of the ASMP promotes partnerships with scientists, industry specialists and policymakers who influence decision-making in relation to shorebird conservation and management. Together, these partnerships provide numerous benefits that promote program stability, leverage funding and resource acquisition, maintain volunteer motivation and deliver impact.

Challenges to maintaining successful long-term projects

Despite their significant and ongoing contributions, both Waterwatch and the ASMP have experienced various challenges impacting project stability and limiting sustained volunteer participation. Ensuring reliability of funding has been a consistent challenge that has affected program coordination, the delivery of resources to support volunteers, volunteer attribution and the capacity to make positive contributions to research, policy and practice.

Additionally, converting citizen science data to information and knowledge through analysis has been a continual struggle for both programs. A constrained ability to produce scientific outputs has made the uptake of citizen science data in policy and decision-making slow or in some cases, non-existent. For example, in the ASMP, anecdotal information started emerging in the 1990s of declines in shorebird species across many monitoring sites (Wilson 2001), but it was not until the program partnered with universities nearly two decades later to help analyse and publicise the findings that the program was able to influence national and international policy (Hansen *et al.* 2019).

The failure to convert volunteer-collected data into information for decision-making can lead to loss of motivation and a decline in participation, impacting the consistency of the monitoring efforts. In the case of Waterwatch, uptake of information from the monitoring has been relatively low, with some notable exceptions (Bonney *et al.* 2020). Without the insights from the monitoring data and the recognition by decision-makers of the value of this information, volunteers may become disenfranchised. For long-term projects to be successful (i.e. persist and generate environmental outcomes), they not only depend on active and sustained participation of volunteers, but also on the willingness of decision-makers and environmental managers to engage with these programs.

Learning from long-term citizen science

In recent years, citizen science researchers have made considerable efforts to distil key principles and best practice recommendations to promote innovative citizen science projects (e.g. Hecker *et al.* 2018; Robinson *et al.* 2019; Steven *et al.* 2019). With a view to building on these studies, we suggest five key factors that are critical in enabling meaningful long-term citizen science programs. These include (1) developing a clear vision; (2) effective knowledge management; (3) relationship building; (4) meaningful volunteer engagement; and, (5) a capacity to adapt to change (Fig. 1).

Developing a vision

Developing an overarching vision of monitoring activities that articulate project purpose, goals and objectives is critical to

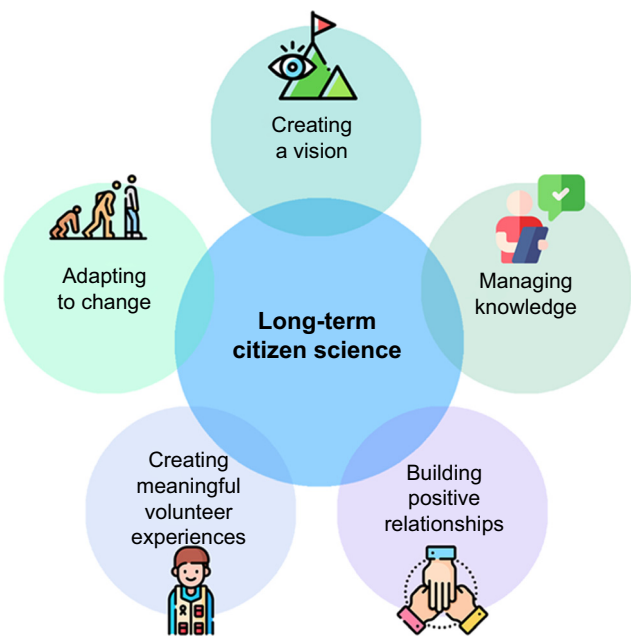

Fig. 1. The five elements that characterise long-term citizen science program 'success'.

citizen science program persistence (Steven *et al.* 2019). Without strategic planning, long-term citizen science projects can lead to 'monitoring for the sake of monitoring' (Conrad and Hilchey 2011), which may discourage longer-term commitment and contribute to volunteer burnout (Byron and Curtis 2002). For nearly 30 years, Waterwatch has been guided by dual goals of raising community awareness of waterway problems and collecting data to inform on-ground management actions and policy-making. Likewise, throughout its history, the ASMP has been underpinned by a need for broadscale monitoring to identify population trends in migratory shorebirds. These goals have anchored both programs and ensured they are conducting activities relevant to local community contexts, but are also supported by the necessary tools and methods to achieve their broad objectives.

Managing knowledge

Knowledge management is about processes and strategies that enable programs to create, store, share and effectively use knowledge to meet desired objectives (Khiste *et al.* 2018). Both Waterwatch and the ASMP have made considerable efforts over their lifespan to ensure effective knowledge management and communication to researchers and decision-makers. These efforts were made in response to an identified need to improve the uptake of data into research and decision-making. Modern knowledge management relies upon ICT and this has become a feature of contemporary citizen science projects, including Waterwatch and the ASMP. However, it is important to acknowledge that, for citizen science projects underpinned by in-person participation, technology should support and rather than supplant field data collection activities. With the rise of smart phones and online information systems, it more possible than ever to build new citizen science programs around technology. However, basing programs solely on technology risks overlooking the importance of volunteer engagement, reducing interactions between participants and scientists (Cappa *et al.* 2016) while constraining the many ways volunteers can contribute to citizen science projects (see for example Box 2).

Building positive relationships

Waterwatch and the ASMP do not exist in isolation. They are both integrated with their respective stakeholder networks through partnerships with government agencies, research institutions and other community-based organisations. These partnerships can take many shapes and forms, from informal networking to collaborations with formal agreements (Himmelman 2001), and play an important role in building local capacity, promoting learning and creativity, knowledge transfer, and improving uptake and trust of the monitoring information. Although positive relationship building is at the heart of all citizen science programs, it is perhaps even more important in long-term projects that need to continue operating regardless of changes to policy, personnel and national research priorities.

Creating meaningful volunteer experiences

Volunteers are the lifeblood of citizen science and, as such, projects must attend to their interests, expectations and concerns (West and Pateman 2016). This aligns with consistent messages in volunteering literature showing that programs generate richer volunteer experiences and are more stable when they satisfy the often diverse and multiple motivations for participation. Waterwatch is increasingly offering diversified volunteer experiences, whether this be in long-term monitoring of their local waterways or more episodic volunteer activities, e.g. Platypus eDNA sampling. The ASMP has created a variety of opportunities for non-scientific contribution, for example, with artists across the East Asian-Australasian Flyway contributing to raising awareness of shorebird conservation through exhibitions in multiple countries (https://www.theoverwinteringproject.com/). Project coordinators are essential in creating or facilitating meaningful volunteer experiences and this requires developing an understanding of volunteer motivations and encouraging novel forms of participation.

Adapting to change

The success of Waterwatch and the ASMP can be attributable in part to past needs to adapt to changing circumstances. Indeed, a capacity to adapt to change, when new information or other changes impact the project, is a hallmark of any successful enterprise. Waterwatch has over time gradually shifted in focus from solely raising awareness of waterway issues to tighter integration of water monitoring data with government priorities. This shift in program focus responded to a need to justify its value to funders and policymakers, leading to improvements to the scientific integrity of monitoring data. Similarly, shorebird monitoring began at a time when there was very little knowledge about shorebirds and their distribution, so early years of the monitoring focused on addressing foundational gaps in scientific knowledge. As evidence began emerging of shorebird population declines, the surveying shifted its focus to obtaining more consistent, site-based and structured monitoring data to inform population trend analyses (Hansen *et al.* 2019). Overall, when such changes to program direction occur, it is important that project leaders engage with volunteers, provide scientific justification for the changes, encourage their involvement in all aspects and recognise the contributions of volunteers. This helps to ensure that projects are designed (or re-designed) based on real scientific and social objectives and reinforce a shared purpose or concern.

Conclusion

Although short-term citizen science projects can have many benefits for science, society and policy, longer-term endeavours have their own distinct advantages. In an era where new citizen science efforts are initiated with no guarantee they will continue to be sustained (i.e. through further funding), there is a need to learn from established projects that have persisted through various social, economic and environmental changes. It is important to continue supporting the rising broad-based interest in citizen science, however research institutions and policymakers should also maintain commitment to pre-existing citizen science programs that already comprise long-term datasets, committed volunteers and strong links with multiple stakeholders.

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