Citizen science for biodiversity benefit

A 2020 scoping paper

S.J. Platt and F. Hames

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Acknowledgment

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it. We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

We are committed to genuinely partner, and meaningfully engage, with Victoria's Traditional Owners and Aboriginal communities to support the protection of Country, the maintenance of spiritual and cultural practices and their broader aspirations in the 21st century and beyond.

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Citizen science for biodiversity benefit—

A 2020 scoping paper

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Technical Report Series No. 355

Preamble

This citizen science scoping paper overviews the potential of citizen science to contribute to public policy and actions, alongside the principles, elements, risks, challenges, and benefits of these programs. This paper demonstrates the significant contribution citizen science provides towards the delivery of '*Protecting Victoria's Environment—Biodiversity 2037*'.

This paper was prepared by Department of Environment, Land, Water and Planning (DELWP), external partners, and collaborators (see acknowledgements below). It was compiled in 2020 to briefly review and synthesise the citizen science literature, summarise key projects, platforms and technologies used in Victoria, and detail case studies highlighting how citizen science projects are established, managed, and implemented in a variety of environments. Originally intended as an internal document, the usefulness for a wider audience was recognised, hence the release of this scoping paper now.

We recognise that several significant events have occurred since 2020, and these events may have affected the ways in which Victorians have valued, connected with, and acted for nature through the practice of citizen science. This includes the global COVID-19 pandemic and associated lockdowns that imposed restrictions on the daily life of Victorians. The restrictions associated with lockdowns affected when, who with, and how often, people could visit nature, and meant several citizen science initiatives, programs, events, and usual practices were no longer taking place. Other citizen science programs grew, such as those people could participate in from home. Despite the recent challenges, citizen science remains a growing and thriving sector in Victoria and releasing this paper in its original authentic form provides a snapshot of the Victorian citizen science landscape in 2020.

We also acknowledge there are emerging policies in development in citizen science that have occurred since 2020. This includes the co-creation of, the yet to be released, *Victoria's Biodiversity Citizen Science Strategy 2023-2033: People-powered research for biodiversity conservation.* The Citizen Science Strategy is led by DELWP and was co-developed with the Victorian citizen science sector, and through engagement with Traditional Owners from various Registered Aboriginal Parties across Victoria. Of note in the upcoming Citizen Science Strategy, is the acknowledgement that deep listening, observations of nature and reading Country is an ancient practice for First Nations people in Victoria and beyond, and this has occurred since time immemorial and continues to this day. The Citizen Science Strategy recognises and embraces First Nations peoples Knowledges and wisdom in the domain of participatory science, and acknowledges that all citizen science in Victoria occurs on Aboriginal land. Other developments include a yet to be released, DELWP Indigenous Data Sovereignty Policy, which is likely to have an influence on citizen science project planning and implementation in the future.

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Context:

In November 2016, the Department of Environment, Land, Water and Planning (DELWP) initiated a project to investigate the potential for citizen science to contribute to delivery of 'Protecting Victoria's Environment – Biodiversity 2037' (DELWP 2017), which was launched in April 2017.

Aims:

This scoping paper considered the potential for citizen science to add to delivery of the two goals of the strategy – a) Victorians value nature, and b) Victoria's natural environment is healthy.

The document may be useful to anyone who is interested in the potential contribution citizen science could make to delivery of a critical public policy objective – the long-term protection of biodiversity. The document also provides advice and direction on the principles, elements, risks, and benefits of adopting an enhanced citizen science program.

Methods:

A brief survey of relevant literature was undertaken and is summarised here. A list of some key citizen science projects in Victoria was compiled, along with case studies that explored more detail on individual projects and programs, how they were established and practical considerations for implementation.

Conclusions:

Citizen science is one of several ways in which citizens can connect with nature, and voluntarily help to protect nature. It offers the opportunity for people to become involved in, and contribute to, meaningful scientific projects. There are substantial benefits for citizens, for communities, for governments, and for the environment, through effective citizen science.

Citizen science is growing rapidly in many countries. This growth is aligned with an escalation in mobile communication devices and similar technologies, which enable increased access and participation, and improved accuracy and confidence in the value of data collected. These developments, along with the launch of 'Protecting Victoria's Environment – Biodiversity 2037', provide a timely context for organisations to explore and embrace citizen science, for citizens and for biodiversity.

The citizen science sector would benefit from improved coordination between supporters of citizen science, an understanding of priority knowledge needs for protecting biodiversity, an easily accessed and comprehensive project 'catalogue' listing opportunities for volunteers, and a capacity to link volunteer interests and skills to projects. For volunteers, excellent training and communication, and reward and recognition are needed, along with a resource hub containing support materials. Several organisations are analysing the role of citizen science in their strategic direction and delivery. The Australian Citizen Science Association (ACSA) identified the needs of citizen science through its 2019-2021 strategic plan (https://citizenscience.org.au/wp-content/uploads/2020/02/ACSA-Strategic-Plan-2019-21.pdf).

The greatest benefits will be derived from citizen science where there are considered and planned approaches to help ensure projects are effective, robust, and meaningful.

We propose that organisations can support an effective citizen science program that supports biodiversity by:

1. identifying the highest priority knowledge requirements for implementing 'Protecting Victoria's Environment – Biodiversity 2037' and filtering them for citizen science project suitability
2. designing and implementing pilot projects that are attractive to volunteers, based on these priorities, in collaboration with behaviour change scientists and partners in the citizen science 'sector'
3. offering a diverse support program that provides valuable services to groups of citizens wishing to design and conduct their own projects and collect scientifically valid data

4. evaluating the program experimentally to determine the extent of behaviour change, the value the data brings to management decisions and ways to improve future activities
5. appointing a dedicated coordinator(s) with the appropriate citizen science skills, experience, and enthusiasm
6. being an active member of the collective sector: by supporting and contributing to a ‘resources hub’ (which contains support documents, connects people and projects, and is linked with the ACSA website), and by participating in a Community of Practice for those involved in citizen science.

1 Introduction

Our understanding of nature, its current status and ways to protect it, relies on people answering important questions and collecting relevant data for analysis. While trained scientists have traditionally taken a lead role in the acquisition of knowledge, for many years citizens have made valuable contributions. The term 'citizen science' identifies this contribution. This report explores citizen science and whether it could play a greater role in conserving nature in Victoria.

1.1 About this document

In November 2016, the Department of Environment, Land, Water and Planning (DELWP) initiated a project to investigate the potential for citizen science to contribute to delivery of 'Protecting Victoria's Environment – Biodiversity 2037' (DELWP 2017), which was launched in April 2017. This scoping paper considered the potential for citizen science to add to delivery of the two goals of the Plan – a) Victorians value nature, and b) Victoria's natural environment is healthy.

This document may be useful for everyone who is interested in the potential contribution citizen science could make to delivery of a critical public policy objective – the long-term protection of biodiversity. The document describes the principles, elements, risks, and benefits of adopting a citizen science program.

A brief survey of relevant literature was undertaken and is summarised here. A list of some key citizen science projects in Victoria was compiled, along with case studies that explore more detail on individual projects and programs, how they were established and practical considerations for implementation. An outline of a state program was developed, which will be further developed as part of implementation planning for delivery of 'Protecting Victoria's Environment – Biodiversity 2037'.

2 About citizen science

In this section, we provide background information on citizen science, including its current status in Victoria.

2.1 What is citizen science?

Citizen science (also called community science, crowd science, crowd-sourced science, civic science, volunteer monitoring or networked science) involves volunteer citizens, in partnership with scientists, participating in scientific endeavours for community benefit.

There is no universally accepted definition of citizen science. The following are some of the many that have been applied:

> *'The collection and analysis of data relating to the natural world by members of the general public, typically as part of a collaborative project with professional scientists.'* (OLD 2017)
>
> *'In North America, citizen science typically refers to research collaborations between scientists and volunteers, particularly (but not exclusively) to expand opportunities for scientific data collection and to provide access to scientific information for community members. As a working definition, we offer the following: projects in which volunteers partner with scientists to answer real-world questions.'* (Cornell Lab of Ornithology 2017)
>
> *'…members of the public contributing to the collection and/or analysis of information for scientific purposes. But, at its best, it's much more than that: citizen science can empower individuals and communities, demystify science and create wonderful education opportunities'.* (Ritchie et al. 2016)
>
> *'A citizen scientist is a volunteer who collects and/or processes data as part of a scientific enquiry.'* (Silvertown 2009)
>
> *'…partnerships between scientists and non-scientists in which authentic data are collected, shared, and analysed.'* (Jordan et al. 2012)
>
> *'Citizen science refers to the engagement of non-professionals in scientific investigations – asking questions, collecting data, or interpreting results. Citizen-science projects generally include a partnership between amateur and professional scientists, although expert amateurs can replace the role of professional scientists. Here, we consider 'amateur' to mean anyone who is not a professional scientist, and do not intend the term to reflect level of expertise, since some amateurs are in fact leading experts in their fields. In some cases, as in analyses of historical data (e.g., information found in journals of natural history observations), partnerships can arise where no direct contact between the amateur and professional scientists occurs.'* (Miller-Rushing et al. 2012)
>
> *'…scientific research conducted, in whole or in part, by amateur or nonprofessional scientists. Citizen science is sometimes described as 'public participation in scientific research', participatory monitoring and participatory action research.'* (Wikipedia 2017).

Citizen science thus has many broad definitions, which can include direct participation in scientific research as well as activities that are indirectly related to scientific research, such as transcribing information in museum collections or reporting a species' location.

The key components of citizen science are that it:

- involves members of the public in a voluntary capacity (unpaid)
- is usually undertaken in partnership with scientists
- applies scientific principles in project design and execution (where appropriate)
- results in collection, analysis, storage, and use of data
- leads to meaningful outcomes for society and participants.

These components and principles of citizen science are expanded upon in Appendix 1.

Citizen science is not a substitute for the professional skills of qualified scientists. It is recognition that a range of skills exist within the community, and that inviting citizens to participate in the scientific process can benefit biodiversity protection and all participants (including volunteers and scientists) and can complement a professional program.

Citizen science is not a new idea. Citizens have recorded their observations of the natural world for centuries (Miller-Rushing et al. 2012; McKinley 2017). Citizen involvement in biodiversity protection and management has a long history in Victoria. The first government botanist and Director of the Royal Botanic Gardens, Baron Ferdinand von Mueller, established a wide network of citizen plant collectors throughout the State, and interstate, during the 1800s, enabling the accumulation of herbarium specimens for scientific research. There are many examples of long-term studies initiated and undertaken by citizens such as the Victorian Wader Study Group, which has collected data on waders and their migrations since 1975, thereby allowing a deep understanding of wader conservation requirements (Clemens et al. 2016).

Encouraging citizens to participate in scientific research – including observation, data collection, data management, analysis, interpretation, and presentation of outcomes – presents an opportunity for citizens to not just be passive recipients of the outcomes of scientific investigations, but to be integrally involved in the scientific process and in ownership of scientific insights into the natural world. Citizen science is viewed in the United Kingdom as a way of democratising science (Irwin 2001). Citizen science may provide an avenue for science to be given a greater voice and to support evidence-based decision-making.

Citizen science can have biodiversity and social objectives. Neither citizen science nor science is an objective in its own right. In this case, both are ways of achieving the goals of ‘Protecting Victoria’s Environment – Biodiversity 2037’.

Citizen science potentially spans a range of scientific disciplines of relevance to ‘Protecting Victoria’s Environment – Biodiversity 2037’:

1. **Biological sciences** – e.g., the distribution and abundance of organisms, their inter-relationships, the threats they face, their condition and extent
2. **Social sciences** – e.g., the knowledge, aspirations, values, and behaviours of the community, particularly those in relation to the natural environment
3. **Environmental sciences** – e.g., the implications of climate change on biodiversity, environmental water requirements
4. **Geosciences** – e.g., the influence of geology and soils on biological systems.

Citizen science can also contribute to scientific research projects that involve:

1. identifying a research question
2. establishing an appropriate study design (e.g., Before-After-Control-Impact, chronosequence)
3. consideration of the need for replication, occupancy and detectability, controls, predictor and response variables and potentially problematic issues of statistical power and confidence, spatiotemporal confounding, appropriate data collection, analysis and interpretation and the scale of measurement
4. reporting/publishing in the scientific literature or sharing the resulting story through other mechanisms.

2.2 Models of citizen science

Different models of citizen science are possible. Projects may be designed by professional scientists; citizens may determine their own priorities, or projects may be co-designed/co-created.

Several types of engagement with citizen scientists are recognised in the literature (Pecl 2015; see also Bonney et al. 2009):

1. **Contributory** – Citizens collect or process data for scientists
2. **Collaborative** – Citizens engage in work beyond data collection or processing, such as project design, analysis, or communication
3. **Co-created** – Citizens and scientists work together in all aspects of the scientific process

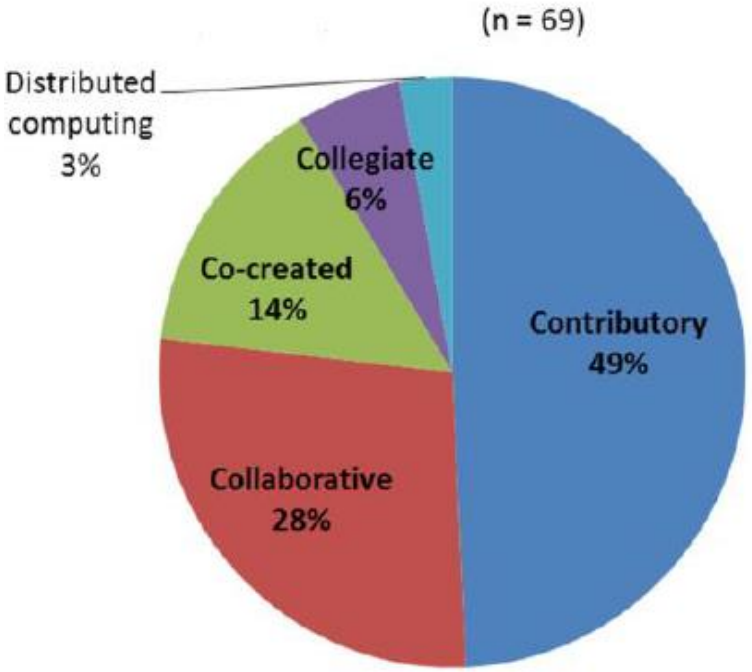
In addition, the authors recognise that projects may be:

Contractual – Citizens identify an issue and contract scientists to assist to run the project.

Independent – Projects are created and delivered by citizens with or without support of professional scientists (e.g., Goongerah Environment Centre; see Appendix 2).

Almost half of Australian projects are contributory (Figure 1). That is, citizens collect data for projects developed by organisations, in comparison to citizen-led projects. (See Appendix 2 for a list of Victorian citizen science projects.)

Co-created projects are not currently common in Australia, but have significant potential for development. An example is the response of the Victorian Environment Protection Authority (EPA) to the 2014 Hazelwood fires. The EPA co-designed a revised air quality monitoring network with a panel consisting of 25 community members (half selected at random and half from established groups). This gave the community a strong voice and high level of engagement in providing input to an issue with wide-ranging community implications.



Contributory (citizens collect data for scientists)

Collaborative (scientists involve citizens in creation and running of projects)

Co-created (citizens and scientists work together to create and run projects – often initiated by citizens)

Distributed computing

Collegiate (citizens running project with no professional scientist involvement)

Figure 1. Proportion of Australian citizen science projects by project type in 2014 (after Roetman 2014)

2.3 Benefits and limitations of citizen science

Potential benefits to science

Potential benefits to science from supporting citizen science include:

1. data breadth, potentially via large numbers of people participating over wide areas
2. access to highly skilled people outside the 'tasking' agency/organisation
3. increased community scientific literacy and social capital, increased issue, or project awareness/visibility
4. learning more about community values, priorities, and engagement
5. different and diverse perspectives and thinking
6. potential increased access to exploring science questions across multiple land tenures, including the two-thirds of Victoria that is private land
7. enhanced co-operative and coordinated investment and effort into environmental protection
8. a low cost-base (unpaid participants; but noting that citizen science does require dedicated investment).

Potential benefits to participants

Volunteering is a choice. Volunteers will choose the level of their commitment based on what they gain from the activity and their personal constraints.

Potential benefits to volunteer citizen scientists include:

1. friendships, improved social networks, participation in enjoyable activities, connection to local people with similar interests
2. participation in worthwhile, meaningful, enjoyable activities with potential to protect nature (sense of purpose and contribution)
3. improved skills and knowledge and/or the satisfaction of using existing skills, connecting with mentors for further skill development
4. health and wellbeing benefits from time spent outdoors in nature
5. a connection with nature and places (particularly local places), including a spiritual connection
6. a sense of achievement and enhanced social status (potentially including via social media sharing) associated with community service
7. the opportunity to choose diverse ways of participating: one-off, short term or long-term commitments; field or desktop; individually or in groups etc.
8. an enhanced understanding of how scientific research contributes to decision making.

Potential limitations

Potential limitations of a citizen science approach include:

1. variation in skill level and experience amongst participants and staff
2. costs of managing people and effective engagement in multiple contexts
3. dispersed authority, potential poor clarity of leadership/source of truth (no hierarchy of staffing as in paid employment)
4. potential unreliability or poor impact of some participants on others (although some volunteers can be very reliable)
5. a limited pool of volunteers suited to projects involving complex tasks, high risk, etc.

A major challenge of using citizen science to deliver biodiversity research outcomes is the level of necessary investment in the important resources required to effectively engage with people, which can be high. Nevertheless, genuine attention to the perspective and needs of volunteers is crucial to

the success of citizen science projects. Involving staff with high level people management skills will benefit projects.

2.4 Technology and citizen science

The success of citizen science projects is critically dependent upon excellent communication and easy-to-use interfaces for data acquisition, that engage people (see case studies, Appendix 3). New communication tools and technologies can handle the large volumes of data that can result from successful citizen science projects.

A wide range of technologies have been applied to citizen science projects (Appendices 2 and 12), and the potential is increasing rapidly as new technologies become available. The value of these technologies in supporting citizen science is being studied by Federation University, amongst others.

Most people carry around a piece of advanced communications technology – their mobile phone – and this has been successfully used for citizen science projects to acquire data (images, sounds, locations) and transmit the data to storage while they receive immediate feedback that enhances the experience (e.g., confirmation of their record being received, how it adds to the volume of data being collected, identification information, thanks for their time and effort).

Recent advances in communications technologies have greatly enhanced the potential for involving citizen scientists and of meeting the evidence requirements of high-quality science. Technologies that can be applied to citizen science include:

1. **apps** – that make connection to the relevant site direct and facilitate two-way communication
2. **citizen science platforms** – e.g., Atlas of Living Australia's FieldData software, iNaturalist, VBA Go (Victorian Biodiversity Atlas), Indicia (UK), Statewide Integrated Flora and Fauna Teams (SWIFFT), Zooniverse (worldwide). Direct webpage upload sites are increasingly appealing, in a world of "app overwhelm".
3. **computer/machine learning** – computers have a capacity to learn about users from their activity and then to deliver targeted messages. For example, a person looking at birds in one location might be encouraged to look at a nearby location with higher data value, or such logic could be used to expand reach and grow participation.
4. **crowd funding** – to source additional resources for projects (e.g., Pozible, Chuffed, GoFundMe)
5. **event management** – to engage and manage volunteers (e.g., MeetUp, Eventbrite, and Facebook Groups, and application in events such as BioBlitzes)
6. **open-source tools** (free) – for content management/website development (e.g., Dupal), blog (e.g., Wordpress), people survey (e.g., SurveyMonkey)
7. **smart phones, iPads** – have inbuilt GPS for location information, capacity to prefill forms, photo, or sound verification capability, simple to use apps (e.g., I Spy Fish/Frogs), can hold documentation and training guides, provide instant feedback to participants, and encourage use through reminders or games. This highly portable technology is now very familiar to, and incorporated into daily use by, most citizens increasing the likelihood of uptake in citizen science.
8. **Social media** – to build networks, enhance volunteer satisfaction, build social norms and status around activities, provide feedback and store data (e.g., Twitter, Instagram, Flickr, Facebook)
9. **Video** – now available on most mobile phones and digital cameras. Can be used to develop visual training materials and posted online (e.g., Youtube), emailed, included in smart phone apps etc.
10. **Wireless sensor networks and remote cameras** – to collect data remotely and transmit it wirelessly for viewing, classification, and storage.

Well-designed user interfaces using appropriate technology are an important determinant of volunteer participation (e.g., Martin et al. [2016a], VNPA case study Appendix 3).

A survey by the ACSA (Roetman 2014) identified websites and GIS as the most important technologies used in citizen science projects (Figure 2). Smart phones and Facebook (and other social media platforms) were considered emerging technologies that will play a greater role in the

future. Roetman's analysis is now several years old, and the relative importance of specific technologies is likely to have shifted, but the core importance of emerging technologies remains clear.

Technologies can have long lead times to develop, test and evolve. For example, Bowerbird – 'an online social, web-based, biological sandpit where everyone can come and play' – was in development by Museum Victoria for 14 years (Norman pers com 2017) and engaged many citizen scientists. Bowerbird now sits within the global iNaturalist citizen science platform.

It is also worth noting that Australia is a relatively early-adopting, fast uptake population with respect to new technologies.

Emerging technologies of benefit to citizen science are discussed in Newman et al. (2012).

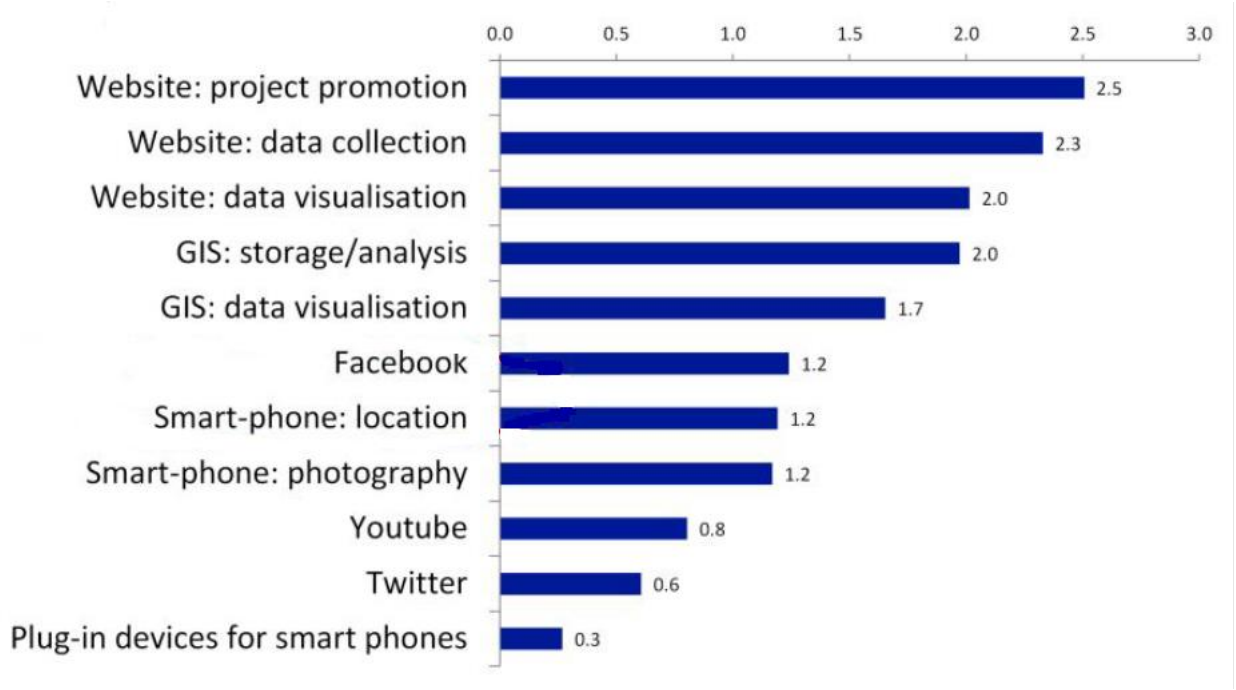


Figure 2. The relative importance of information and communication technologies to citizen science (after Roetman 2014).

2.5 Who is involved in citizen science?

A national survey of 122 citizen science project leaders conducted by the Australian Citizen Science Association (Roetman 2014) found that:

1. a wide range of organisations are involved in citizen science (Figure 3)
2. universities, community groups and state governments are significant contributors to citizen science projects.

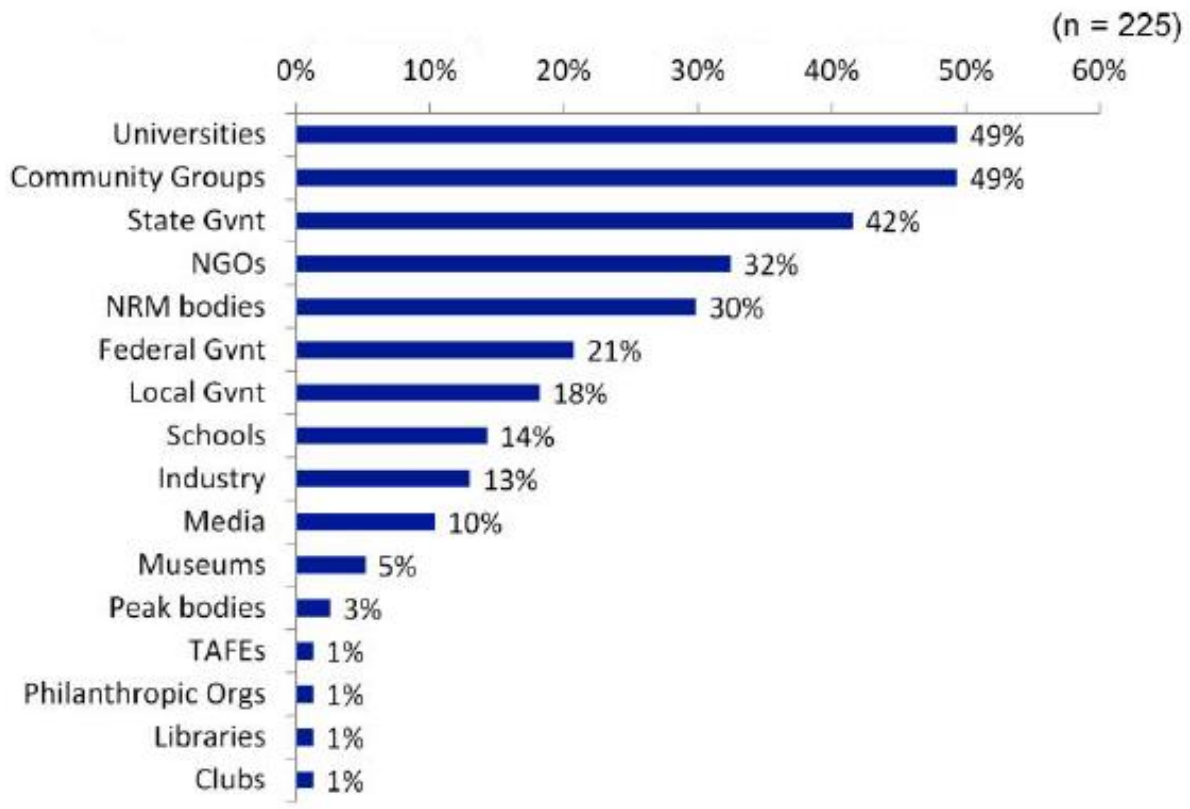


Figure 3. Organisations contributing to citizen science projects in Australia (after Roetman 2014)

Peak body

A peak body for citizen science, the Australian Citizen Science Association (ACSA), was incorporated in 2016. Regional chapters have been established, including in Victoria. The ACSA is evolving and growing; it has a website, a strategic plan, publishes a regular newsletter, shares resources and links to projects, and keeps in contact via social media and Google Groups (citizenscience-australia@googlegroups.com).

Several other organisations also employ citizen science coordinators, including the Victorian Environment Protection Authority (EPA), Victorian National Parks Association (VNPA), DELWP, Melbourne Water and BirdLife Australia.

Partnerships

Partnerships are often critical to the delivery of successful citizen science projects. In a review of the Melbourne Bioblitz by Ives et al. (2015), the authors state that 'one of the biggest lessons that we learned from the experience is the value of collaboration between different organisations and individuals within the city. The BioBlitz was supported by a range of partners (Museum Victoria, RMIT University, University of Melbourne, the Australian Research Centre for Urban Ecology, naturalist groups, 'Friends of' groups, non-government organisations, and many natural resource management agencies).'

Volunteer sources

Citizen volunteers come from a very wide range of sources such as Friends groups, schools, SCUBA diving clubs and universities (Appendices 2, 7). Independent individuals are also active in citizen science, initiating projects for which they have a passion (e.g., collecting bird sightings at a local reserve).

With advances in communications technology, citizens can be located anywhere in the world and contribute online to some citizen science projects (e.g., viewing remote camera images of wildlife).

Volunteer type

Many citizen science volunteers are individuals with skills learned during their career or other activities, and with available time.

Participants in two US projects were described as: '… sharing some common attributes; for the most part, they were locally based and self-selecting and represented a similar demographic, with the majority being female and over age 50. This profile resembles that found in other citizen science projects' (Toomey and Domroese 2013).

In relation to a marine project, Martin et al. (2016a) found that 'the most enthusiastic tended to have a higher education in science, were under 45 years old, primarily enjoyed SCUBA diving, and had contributed to scientific research in the past.'

The role of the 'champion'

The 'champion', being one or more individuals who are passionate about a project and put in the extra time and energy required to motivate others until the project achieves its outcome, is important to the success of many citizens science projects.

Like all 'carers', champions need to be supported and their efforts recognised and valued. Giving them a break in duties to rest and recuperate may help avoid burn out and assist in promoting the longevity of their contribution.

Champions may benefit from leadership training enabling them to become mentors to new or younger volunteers joining a project.

In selecting projects for funding, identifying the champion(s) is relevant to an assessment of project viability. Effective champions are a significant asset to a project.

The role of 'professional' amateurs

Members of the community with high levels of knowledge gained in a private capacity or through previous professional roles have a lot to contribute and are a key audience for recruiting citizen scientists. Contact with this part of the community can usually be made via natural history and science associations or through advertising online or via relevant publications.

2.6 Types of activities undertaken by citizen scientists

Within Australia, citizen scientists are involved in a wide array of projects across many subject areas (Appendix 2). In regard to biodiversity, citizen scientists report species sightings (e.g., via Atlas of Living Australia, Victorian Biodiversity Atlas, Feralscan [invasive species], Wildlife of the Central Highlands [WOTCH]), participate in site surveys (e.g., marine fish, bird counts) undertake monitoring (e.g., BioBlitz, Waterwatch, nestboxes) and share information (e.g., SWIFFT). Projects may involve field sampling (bird counts) and/or virtual sampling, which encompasses searching images or maps online (e.g., Digivol, Wildlife Spotter). Targeted locations can be remote or urban; for a review of the Melbourne Bioblitz see http://www.thenatureofcities.com/2015/03/01/citizen-science-in-the-city-lessons-from-melbournes-bioblitz/

Complex analyses are not usually expected of citizen science volunteers, but some expert volunteers could potentially offer these services (e.g., iNaturalist have experts who assist in identification of submitted records).

In some instances, citizen scientists have sought to duplicate protocols of research projects, in novel localities. For example, a DELWP study of hollow-bearing tree collapse rates due to planned burning in Gippsland informed a similar study at Kirth Kiln in the Dandenong Ranges, which was undertaken by local citizens concerned about planned burning.

Internationally, citizen science has contributed to knowledge of migrations, population dynamics, phenology, and pest outbreaks (Miller-Rushing et al. 2012).

Project types can be classified as (see Appendix 2 for more examples):

1. **surveys** – rapid surveys/targeted species surveys – e.g., Great Victorian Koala Count, Fungimap.
2. **monitoring** – birds, wildlife, insect pollinators, etc.
3. **research** – impacts of fire, invasive species
4. **digitized collections** – identifying species in images, transcribing information.

2.7 Citizen's project preferences

In 2016, the Office of Environment and Heritage NSW undertook a survey of 500 people to understand their relationship to citizen science (OEH 2016).

The most popular types of projects for volunteers included those that would help iconic and threatened species survive (38% indicated 'definitely'). The project with the least amount of, but also variable interest, was for domestic cat monitoring using tracking (35% said 'definitely not'), although there were many 'perhaps' (42%) and 'definitely' (23%) responses.

Volunteers assess projects from multiple perspectives. Hobbs and White (2016) stated 'Participants were motivated by personal wellbeing factors such as enjoying proximity to the study species, learning and social factors. Volunteers will also be influenced by their assessment of the 'worth' and meaning of the project and how well it is managed.

2.8 The current state of citizen science

The international context

In 2016, a new online, open access, interdisciplinary and international journal focussing on citizen science was launched in the United States (Bonney et al. 2016; see also Ellwood 2017). The authors describe the status of citizen science thus:

'The field of citizen science is growing with breathtaking speed. Thousands of citizen science projects are now under way around the world, engaging millions of individuals in the process of scientific discovery. In the US, citizen science has been featured at the White House and the federal government has launched a website to showcase federally funded citizen science projects (citizenscience.gov). The largest research and innovation funding program in the European Union, Horizon 2020, is investing heavily in citizen science to tackle societal problems. The Australian government has published a vision for citizen science throughout the country (Pecl *et al*. 2015). Three professional associations supporting citizen science have recently been launched: The Citizen

Science Association (CSA; citizenscience.org), the European Citizen Science Association (ECSA; ecsa.citizen-science.net), and the Australian Citizen Science Association (ACSA; citizenscience.org.au/). Some researchers consider citizen science to have emerged as a distinct field of inquiry (e.g., Jordan et al. 2015). Dozens of articles focused on citizen science are appearing every month, some in prestigious journals such as *Science, Nature*, and *Bioscience*, and a number of journals across a huge range of disciplines recently have or soon will publish special issues on citizen science, including *Ecology and Society, Journal of Science Communication, Journal of Microbiology and Biology Education, Conservation Biology, and Biological Conservation*.'

Australia

In Australia, the current level of participant interest in citizen science is high, and has been fairly high for several years (as indicated by google.com.au/trends; Figure 4):

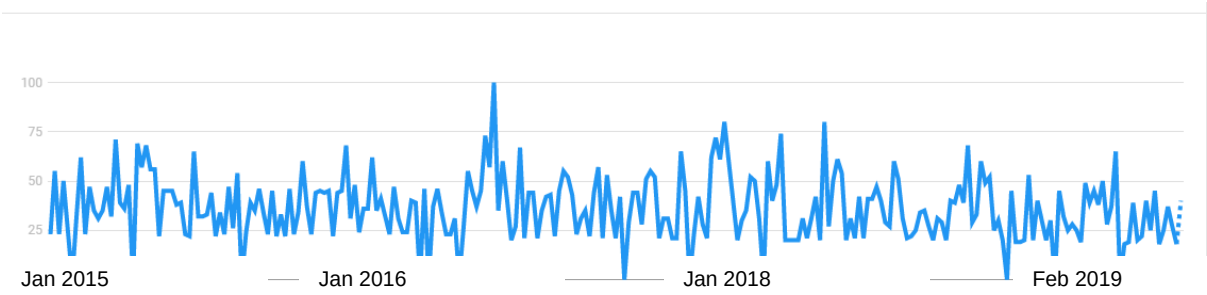


Figure 4. Google searches for the term 'citizen science' between 2015 and 2019

The current level of Australian non-government and government organisational interest and activity in citizen science is also high and increasing. The NSW Office of Environment and Heritage has employed a full-time citizen science coordinator, has published a policy supporting citizen science and developed a citizen science strategy. Queensland has developed a Strategic Plan (the Department of Environment and Heritage Protection (Qld) Strategic Plan 2016–2020), which aims to 'Promote greater involvement of citizen science…'. Parks and Wildlife (WA) has incorporated citizen science (Camera Watch) in their signature predator control program 'Western Shield' (DPAW 2017). The Commonwealth Department of Industry, Innovation and Science announced recent rounds of citizen science grants (e.g., Australian Government 2017).

Victoria

In Victoria, there are many citizen science projects underway supported by a wide range of institutions including not-for-profit and government (Appendix 2). Case study interviews with some of these organisations indicate that interest is high and that recruiting sufficient volunteers for projects has not been a significant issue (Appendix 3).

There is no single source of contact with citizen science projects. Numerous websites allow projects seeking volunteers to list their activities (e.g. Atlas of Living Australia, Wikipedia, The Centre for Volunteering, Do Something Near You, and ACSA's website https://citizenscience.org.au/acsa-vic/). In developing the list shown in Appendix 2, it became evident that numerous independent projects are being undertaken by groups and individuals that may not appear on any formal list of citizen science projects. The list of citizen science projects in Appendix 2 is by no means exhaustive.

Dozens of citizen science projects are underway, collectively involving thousands of citizens. Some projects have existed for over 40 years.

The ultimate potential for growth in citizen science is unknown. The citizen science sector in Victoria is currently relatively small and many potential audiences have not been exposed to citizen science. An Office of Environment and Heritage NSW (OEH 2016) survey of motivations found that many people surveyed said they may consider taking part in citizen science (with 30% 'yes definitely' and 47% 'maybe'). A higher proportion of professionals said they would definitely consider taking part in citizen science compared to non-professionals (40% compared to 28%). It could be reasonably assumed that, with the right approach, considerable future growth in citizen science participation is possible.

Complementing the capability and potential of what already exists (sector organisations, projects and supporting infrastructure) is an important consideration for any future program. DELWP is leading the development of a statewide Citizen Science Strategy, in collaboration with key sector partners.

Victorian examples of citizen science making a difference

Birdlife Atlas Data Project – Since 1998, a dedicated band of over 7,000 'atlassers' have amassed over 420,000 surveys, comprising over 7.1 million bird records. These provide a quantitative measure of how birds are faring across the country and contribute to our understanding of which species are at risk. A new Birdata app for mobile phones makes contributing simple.

Fungimap – Volunteers have collected thousands of records of fungi and in so doing have increased our knowledge of fungal distribution and status. This is essential to conservation planning and management.

Victorian Wader Study Group – For almost forty years, 237,202 individuals of 38 wader species have been banded and 46,791 re-trapped. Understanding of migratory patterns has led to international protection of shorebirds, such as through the Ramsar Convention, and positively influenced planning decisions affecting wader habitat.

A network of practitioners in Victoria has been established, and has formed a Victorian Chapter of the ACSA (https://citizenscience.org.au/acsa-vic/). Participating organisations include:

BirdLife Australia	DELWP, Arthur Rylah Institute
City of Melbourne	Environment Protection Authority
EstuaryWatch	Fungimap
Melbourne Water	Museum Victoria
Parks Victoria	Royal Botanic Gardens
The Nature Conservancy	Victorian National Parks Association
Victoria University	Waterwatch.

2.9 Enhancing the citizen science sector

The citizen science 'sector' refers to those organisations with an interest in citizen science. The Australian Citizen Science Association has developed a strategic plan to create a 'community that supports, informs and develops citizen science'.

Analyses of the existing strategic plans and recommendations in the literature suggest that citizen science in Victoria would be enhanced through:

1. Sophisticated coordination across the sector to avoid duplication, share experiences and resources, simplify client experiences (including setting service standards), and ensure volunteers are directed to the opportunities they are interested in (not lost). Citizen science forward planning and sector leadership are in their early stages.
2. Developing a clear understanding of the priority knowledge needs/research questions of most benefit to biodiversity outcomes.
3. A sector-wide electronic system for linking volunteer interests and skills to projects (e.g., ACSA's citizen science Project Finder https://citizenscience.org.au/ala-project-finder/ partly fulfils this need).
4. A catalogue and prospectus of meaningful and viable citizen science projects suited to a wide audience with clear outputs and outcomes.
5. Online training modules for volunteers using the latest technology (e.g., modules on 'induction to being a citizen scientist', 'principles of experimental design', 'safe work practices during fieldwork', and 'use of equipment', or specific modules such as 'how to identify insect pollinators') and potentially providing accreditation, such as those created by the Clean Air Urban Landscape Hub (CAUL).
6. The option of leadership training for 'champion' citizen scientists and professional scientists.

7. A resources ‘hub’ for scientists to access relevant toolkits and support materials relating to the sector
8. An equipment register, and established policy and procedures for sharing of agency/government-owned equipment with other organisations (such as those developed by DELWP to support monitoring of Leadbeater’s Possum).
9. A sector-wide communication plan and templates to support the development of project- or organisation- specific communication plans.
10. Regular celebration of the achievements of citizen scientists with a high level of community visibility and status (e.g., annually during National Volunteer Week in May, National Science Week in August, or Biodiversity Month in September).
11. Baseline monitoring and independent evaluation of the value of citizen science and its contribution to the outcomes of projects to protect biodiversity.

The ACSA’s co-operative approach to identifying and addressing sector-wide needs could ‘spread the load’ and hasten delivery of a more sophisticated and effective system for growing citizen science in Australia. Organisations would benefit by being active members of the ACSA.

3 Citizen science and biodiversity in Victoria

3.1 'Protecting Victoria's Environment – Biodiversity 2037'

'Protecting Victoria's Environment – Biodiversity 2037' was released in 2017 as the Victorian government's plan for conserving biodiversity in Victoria. It contains two goals:

- Victorians value nature
- Victoria's natural environment is healthy

Citizen science is identified as a new and important tool for achieving the plan's goals. It sets a target that by 2022 'More people are undertaking effective action for the environment, including through "citizen science"' (DELWP 2017, p15).

Citizen science has the potential to contribute to both goals of 'Protecting Victoria's Environment – Biodiversity 2037'.

3.2 Citizen science, values, and behaviours

'Protecting Victoria's Environment – Biodiversity 2037' envisages a range of actions to support the goal of Victorians valuing nature, one of which is support for citizen science. People choosing to participate in citizen science will do so based on their values, and the kind of actions they currently do, or could choose to become involved in.

Values are long-lasting beliefs about what is important to a person and are influenced by many factors such as culture, education, and relationships. Values and beliefs are good predictors of human behaviour.

The types of behaviours that can benefit nature include giving time (e.g., volunteering), giving money, living, and working sustainably, advocating for and, in the case of land managers, incorporating biodiversity into land and water management. Volunteer citizen scientists, having chosen to give their time, may already have values and beliefs that align with protecting nature.

The pathway for people to become actively involved in volunteering is likely to involve numerous interconnected steps. People might be interested in becoming involved because of several motivations, including nature connectedness and concern, skill application or growth, or social motivations. The first step is exposure to the opportunity of contributing and initiation of an interest to do so. The process for expressing interest should be clear and welcoming, and volunteers should receive immediate follow up encouragement and advice on next steps. Once engaged, skills training, mentoring and feedback can build confidence, capability, and connectivity. At this point, many participants should feel welcome and valued, and that they are able to make a significant, meaningful contribution. Ongoing feedback, connections and updates should support people maintaining interest.

The contributions of citizen science to social and environmental outcomes are still being evaluated. Some studies (e.g., Haywood et al. 2016, Hobbs and White 2016) have found that participation in citizen science leads to increased knowledge of science and conservation biology, and has positive social outcomes for participants. Clear evidence of citizen science leading to long-term behaviour change that benefits biodiversity is currently limited but increasing (Toomey and Domroese 2013). Such studies are confounded by prior interest in nature leading to participation in citizen science projects. The long lead time between an action and a biodiversity outcome is also problematic for study design given the relatively short duration of many citizen science projects. People may be attracted to citizen science for many reasons, including for social benefit (Boulet pers com 2017). The attribution of citizen science as the driver of change in behaviour is thus a challenge that is best met by an experimentally designed program evaluation (see examples below).

In a study of 432 participants in a seabird survey, Haywood et al. (2016) found that 'a place-based, data-rich experience linked explicitly to local, regional, and global issues can lead to measurable change in individual and collective action, expressed in our case study principally through participation in citizen science and community action and communication of program results to personal acquaintances and elected officials'.

Ballard et al. (2016) analysed 44 citizen science programs across three museums (one U.K., two U.S.) to assess whether and how they contribute to conservation-relevant outcomes. They 'found evidence that they support conservation both directly, through site and species management, and indirectly through research, education, and policy impacts'. Brossard et al. (2005) and Haywood et al. (2016) found evidence of an impact on participant's knowledge of biology and skills.

3.3 Opportunities and risks

'Citizen science can significantly contribute to scientific knowledge, as well as increasing public engagement and awareness of conservation issues.' Lambert 2014.

To assess the potential of citizen science to contribute to the knowledge requirements of 'Protecting Victoria's Environment – Biodiversity 2037', those requirements need to be sufficiently explicit for analysis. The level of project detail required to assess a potential fit with citizen science is indicated by the decision framework in Appendix 6.

3.4 Potential contributions of citizen science

Contribution to 'Victorians value nature'

'Protecting Victoria's Environment – Biodiversity 2037' (DELWP 2017, p15) envisages increasing the number of Victorians who a) connect with nature, and b) act to protect the natural environment, with targets for 2037 of 'All' and 'five million', respectively.

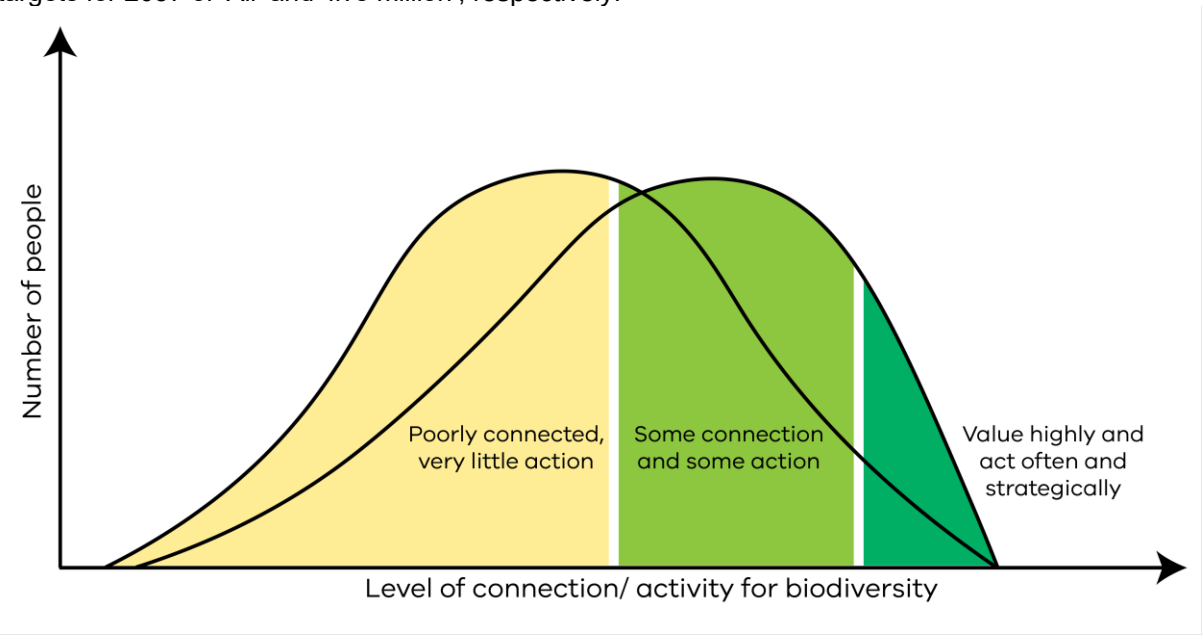


Figure 5. Cost-effectively increasing the level of connection to nature and action for biodiversity

As shown in Figure 5, citizen science's contribution to these targets can most efficiently be achieved by selectively engaging with people who are on the cusp of/amenable to change. That is, their values and beliefs partially align already, they have the time available, their peer group is supportive, and they have previous training, experience, and skills to offer.

Opportunities, risks, and potential treatments for encouraging Victorians to value nature through citizen science are listed in Table 1. Citizen science has the potential to develop pro-environmental attitudes and behaviours and engage citizens in caring about and advocating for the environment.

Table 1. Opportunities, risks, and potential treatments for encouraging Victorians to value nature through citizen science.

Opportunities
a) To increase the number of volunteers who connect with, and place greater value on, nature.
b) To increase the number of community members taking action to support biodiversity.
Risks
• Victorians do not recognise the threat to biodiversity as being seriously in need of their attention. • Citizen science projects offered do not attract volunteers. • Potential volunteers see science as too hard/something they couldn't do. • Insufficient numbers of volunteers to meet 'Protecting Victoria's Environment – Biodiversity 2037' targets. • Volunteer expectations are not matched with reality in terms of what can be achieved through a project they participate in. • Exposure to potential critique for failing to manage projects adequately or respond to their outputs. • Informed citizen scientists burn out or are demoralised by a lack of follow-up action. • Volunteers' participation in citizen science does not increase the value they place on nature. • Volunteers' participation in citizen science does not deliver actions to support biodiversity.
Potential treatments
• Deliver 'Protecting Victoria's Environment – Biodiversity 2037' communication strategy. • Design projects which are enjoyable, achievable, and meaningful. • Target people most likely to adopt the desired new behaviours (i.e., act as citizen scientists), with promotion targeted at effectively reaching those audiences. • Communicate clear expectations of the role volunteers will play in the project and potential outcomes of the project results, and encourage co-creation. • Set realistic expectations for the number of likely participants, create engagement strategies for each project, including brief 'learn about citizen science' sessions. • Encourage two-way communication throughout project development and delivery, to expose concerns and ensure they are addressed. • Provide adequate resources and training for staff to coordinate and manage projects and provide effective communication. • Promote positive channels for achieving improved on-ground outcomes; provide information on the range of organisations actively pursuing better environmental outcomes. • Design projects to provide powerful positive connections with nature. • Provide clear information about how the information is making a difference. • Ensure projects involve actions that genuinely inform priority biodiversity knowledge needs and/or support biodiversity in other ways (e.g., help to understand what level of action people are prepared to take for biodiversity). • Share the stories: give visibility to the efforts, enjoyment, and impact of citizen scientists.

For citizen science to achieve the social goals of 'Protecting Victoria's Environment – Biodiversity 2037', it will need to incorporate the desired behaviours or link to extended programs that do. Getting advice from behaviour change specialists in program design and implementation is likely to be of considerable benefit (see 'Changing people's behaviours' Section 4.5).

Strategies that could be used by a citizen science program include:

- engaging with behaviour change specialists to develop a plan
- working with smaller groups to establish the social norm before recruiting others into the established norm
- offering volunteers a choice of small steps they are willing to take toward a desired behaviour
- recognising high level data collectors, leaders/champions, long-term volunteers, those who donate time or funding to the environment
- working with the sector to develop training programs (delivery via YouTube and face-to-face)
- providing a range of opportunities for participation to enable 'fit' with respect to timing, capability, etc.

As well as collecting data about biodiversity, citizens may also be engaged in other scientific disciplines relevant to 'Protecting Victoria's Environment – Biodiversity 2037'. For example, citizens could be given the opportunity to collect social data relating to:

- people's, knowledge, attitudes, skills, aspirations, and behaviours toward nature/wildlife/landscapes/ policy
- what 'turns people on' to biodiversity? The barriers and constraints to acting for biodiversity
- acceptable options for wildlife management
- funding for nature conservation
- testing whether participation in citizen science improves empathy for nature and effective actions and/or advocacy for the environment.

A key action is to identify social science partners and work with them to determine:

1. the best approach to achieve the desired behaviour change
2. the priority social science data and research needs to support 'Protecting Victoria's Environment – Biodiversity 2037'.

A citizen science program should consider the need to ensure that knowledge gained improves management actions, and that volunteers are steered toward ongoing appropriate behaviours. This may require linking volunteers to ongoing support beyond the life of a specific citizen science project.

See Figure 6 for an overview of a pathway to a successful program.

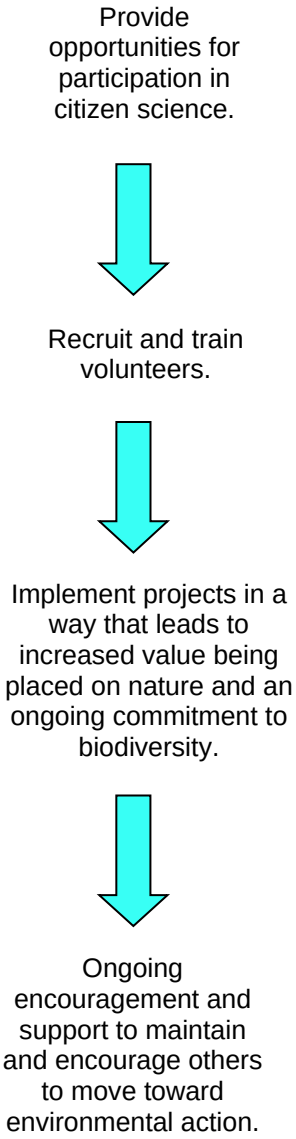


Figure 6. General pathway to a successful program contributing to people valuing nature

Contribution to 'Victoria's natural environment is healthy'

'Protecting Victoria's Environment – Biodiversity 2037' aims for Victoria's natural environment to be healthy with a statewide target of a 'net improvement in the outlook across all species by 2037, as measured by Change in Suitable Habitat' and a '100% net positive Change in Suitable Habitat in 50 years' (DELWP 2017, p19-20).

For citizen science to make the maximum possible impact, organisations need to identify the research questions that will have the most value in managing biodiversity. For example, data that informs management decision models (e.g., species distribution models), including absence data, or costs, can strengthen decision-support tools and thus be of higher value than general species searches (see Table 2 below). Figure 7 summarises the key steps to a successful citizen science program contributing to the goal of a healthy environment.

Table 2. Opportunities, risks, and potential treatments for citizen science to help achieve the goal that by 2037 Victoria's environment is healthy.

Opportunity • To collect and analyse data, targeted at key gaps in knowledge, to improve understanding and management of biodiversity.
Risks • Low value data collected. • Poor data quality. • Data loss. • Unreliable workforce. • Contested decision-making. • Conflicting project objectives. • Science versus people focus. • High transaction costs. • People 'gaming the system' (false, misleading inputs or omitting to report data to influence a decision). • Sample bias.
Potential treatments • Careful project development to target key areas of knowledge for which data is yet unavailable. • Design tasks to maximise data quality (including consideration of smart technology opportunities). • Clear task descriptions, including clarity around the 'why' and consideration of multiple learning preferences. • Training and classifying volunteers according to skill level. Continuous auditing of data collection paying particular attention to dubious records. High skill volunteers helping those with lower skills (e.g., to identify species). • Centralised data storage, electronic data collection, strict protocols on timelines for data to be submitted. • Careful matching of people to roles. Build in resilience by encouraging participants to commit to dates, and by using buddies or teams (particularly around critical roles). Training and supervision. • Inform participants at the outset about the decision-making process; clarify expectations. • Clarify the purpose of the project in the project plan – social outcomes/biological outcomes. • Ensure staff with good people skills are involved in the project. • Consider targeting people with existing skills to reduce transaction costs. • If gaming is likely, implement gaming-proof processes (the recent process for submitting camera records of Leadbeater's Possum, gathered by volunteers, is a good example of tight data requirements) or do not apply citizen science. • Where considered particularly important, increase auditing of data and supervision, and provide transparent, clear advice on decision-making processes or avoid use of citizen science. • Project design should address sampling bias.

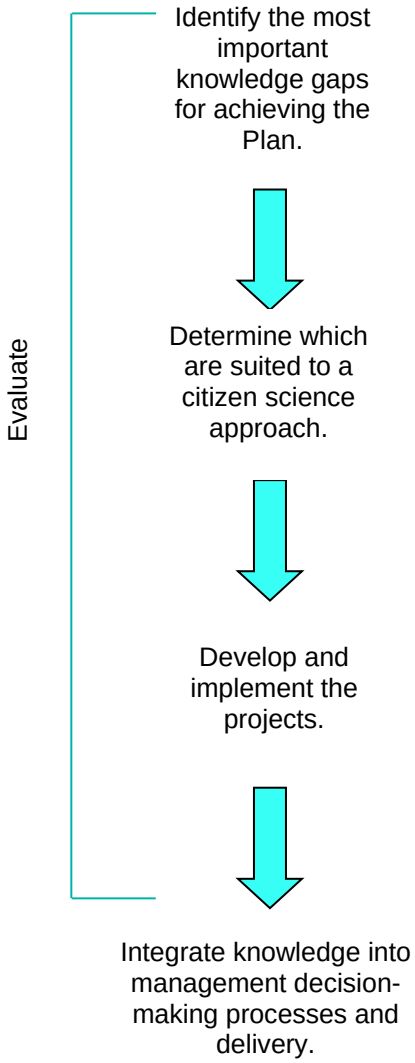


Figure 7. General pathway to a successful program contributing to the goal of a healthy environment

To protect biodiversity, it is necessary to know where knowledge is inadequate to ensure that appropriate management occurs. That is, where is the greatest uncertainty, in what locations and about what species and ecosystems? Once these knowledge gaps have been identified, projects to address them can be developed (Figure 7). Among these, some will be suited to a citizen science approach (see what makes a good citizen science project in Table 3, and Appendix 6). Hence, a key action is to identify strategic knowledge requirements and priority data needs of 'Protecting Victoria's Environment – Biodiversity 2037'.

Targeting critical knowledge gaps can ensure that the work of citizen scientists makes the most valuable contribution to biodiversity protection. It can also ensure that citizen scientists understand how, why, and where their input contributes to meaningful outcomes, which is an important driver for them.

We envisage that, initially, a multi-stakeholder workshop is required to identify critical knowledge gaps for Victoria's biodiversity. This baseline could be built on over time as projects identify their uncertainties and evaluation of project outcomes signals where significant improvement is needed.

What knowledge is needed?

'Protecting Victoria's Environment – Biodiversity 2037' acknowledges gaps in knowledge and effort. In particular, it notes that 'more work is needed to improve knowledge and understanding of marine systems and ecological processes, such as fire, and deliver measurable results'. The importance of knowing how to ameliorate threats effectively is also a key element of the plan. In relation to climate change, the plan envisages direct manipulation of populations and individuals including translocation of species. These actions have associated knowledge gaps that could potentially be addressed through citizen science.

A 1999 review of biodiversity research initiatives for Victoria (NRE, 1999) noted the need to move from 'autecological studies focussing on species and their immediate environment, to synecological studies that focus on processes and interactions between communities and the way in which key disturbances influence the structure and sustainability of these communities and ecosystems'.

Table 3 is included as an example of how the types of knowledge required to inform management of biodiversity and the potential for citizen science to play a role in contributing to that knowledge could be described. Organisations could work with key stakeholders to develop such a framework and so identify where citizen science could play the most useful role in informing the knowledge base required to protect biodiversity.

High value projects will be those that:

- fill critical gaps in knowledge, particularly gaps in data underpinning management models
- address multi-species, landscape issues such as fire, environmental water, and pest animals
- give managers the greatest level of confidence that their actions will be effective.

We do not need to know all the details of all species to manage them effectively. The key is to understand the critical issues, particularly relating to ecosystem function. Therefore, biodiversity surveys (e.g., Bioblitz, Bioscan, Microblitz) should be limited to locations where inadequate basic data on species presence exists. Monitoring should take a greater role than at present, particularly in testing the assumptions in projects. Resolving issues relating to implementing on-ground biodiversity projects effectively should have a high priority.

Table 3. Types of data that are needed to inform 'Protecting Victoria's Environment – Biodiversity 2037'. The table contains examples and is not exhaustive. The potential for citizen science to contribute, in general, is indicated as HIGH – green, MODERATE – dark blue, LOW – light blue text.

Goal: Victorians value nature	Data/knowledge that inform behavioural models	Data/knowledge on the extent to which people value nature	Data that inform government's capacity to manage wildlife issues	Data/knowledge that evaluate the effectiveness of 'Protecting Victoria's Environment – Biodiversity 2037' social goals
	Impact of behaviour change programs. Initiating people's interest in protecting biodiversity, especially those people who are not currently involved. **High** How to get more people of all ages, including business, to live sustainably, donate time and money, and advocate for biodiversity. **High**	Proportion of Victorians by category (business, school, retired etc.) that live sustainably, donate time and money, and advocate for biodiversity. **High**	Community acceptance of wildlife management options/trade-offs. **High**	Effectiveness of social programs for people to value nature. **High**
Goal: Victoria's natural environment is healthy	**Data/knowledge that inform, and provide confidence in, decision-making models**	**Data/knowledge that inform regulation and approvals**	**Data/knowledge that inform on-ground management decisions/actions**	**Data/knowledge that evaluate the effectiveness of management interventions (monitoring & evaluation)**
Species distribution and abundance	Presence/absence of species in areas predicted by species distribution models Shifts in range of 'at risk' species. **High**	Distribution of threatened species e.g., Green and Golden Bell Frog, Striped Legless Lizard, Leadbeater's Possum, Greater Glider. **High**	New species records for a site. **High**	Status of threatened and declining species. **Low due to risk to species and difficulty in locating but may suit high capability individuals.** Presence of target species in restoration/revegetation sites. **Moderate depending on ease of recording the species.**

Species biology	Critical gaps in knowledge e.g., spawning sites of 'at risk' fish, reasons for decline of woodland birds. Moderate depending on ease of recording the attribute/ investigating the cause	Effects of control methods (e.g., koala contraception) on wildlife management. Moderate depending on ease of recording the attribute.	Data/knowledge that assists species recovery e.g., Helmeted Honeyeater survivorship. Low due to complex nature of most questions.	NA
Ecosystem function	Ecologically appropriate fire/environmental water regimes. **Moderate depending on ease of recording the attribute.** Effects of fire/timber harvesting on hollow availability. **Moderate depending on volunteer availability and training.**		Effects of management interventions on ecosystem function. **Low due to complex nature of most questions.** Phenology of 'at risk' ecosystems (e.g., grasslands, woodlands). **High – has been an area of focus for citizen science in the past.**	Ecosystem health assessment. **Moderate – could add to a statewide assessment by sampling particular sites.**
Ecosystem threats/status	Presence/absence of invasive species in areas predicted by SDMs. **High if involving naturalists.** Effective feral cat control. **Low due to detectability.**	Impact of licensed/permitted activities (e.g., deer hunting, wild dog control and off target species). **Low due to complex nature.**		The effectiveness of management interventions to address key threats (e.g., pest plants and animals) **Moderate depending on location/complexity.**
Ecosystem restoration	The effectiveness of management interventions to address key threats (e.g., fishways, environmental water allocations). **Moderate depending on location/ complexity.**	The extent to which offsets are comparable with losses. **Moderate depending on location/ complexity.**	Cost effective restoration of threatened ecosystems e.g., Victorian Volcanic Plains grasslands, Grassy Woodlands. **High for sites close to urban populations.**	Whether restoration benefits the species it is intended to benefit. **High if the species is reasonably detectable.**

More people using their skills to improve knowledge of biodiversity

The task of conserving biodiversity is huge. Increasing the number of people involved is therefore a logical step in addressing this problem. By inviting all citizens to participate in biodiversity protection, organisations can increase the level of human resources available to protect, manage and restore biodiversity on behalf of the community while also offering an opportunity for everyone to benefit from being involved in studying biodiversity.

'Investing together to protect our environment' is a major theme of 'Protecting Victoria's Environment – Biodiversity 2037' (DELWP 2017, p34). Biodiversity conservation requires a collective effort, spanning the voluntary, philanthropic, government and corporate sectors. The plan envisages publishing an investment prospectus as a priority. It could include opportunities to invest in citizen science projects.

Figure 8 summarises the pathway to more people using their skills to improve knowledge of biodiversity.

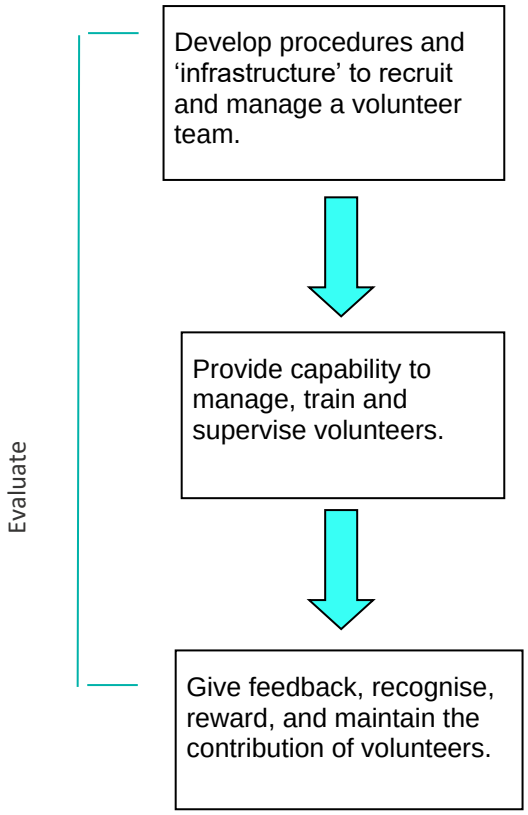


Figure 8. General pathway to a successful program for increasing capacity and capability

Table 4. Opportunities, risks, and potential treatments for increasing capability and capacity through citizen science

Opportunity
To increase the number of people acquiring biodiversity knowledge by involving additional people in scientific activities and information collection, thereby enhancing the capacity to undertake more high-quality research, increasing reach (spatially, temporally), accessing skilled and experienced people, and potentially crowd sourcing funding for research activities.
Risks
• Risk of injury – the risk of health and safety incidents with the use of volunteers is likely to rise. • Cost versus benefit – costs involved with the training, supervision, communication, and reward of volunteers may exceed the potential benefits. • Unreliability – volunteers cannot be expected to work reliably to strict working hours, or on particular days. • Goal mismatch (e.g., volunteers see citizen science primarily as an entry to a career).
Potential treatments
• Avoid using volunteers for high-risk projects (e.g., involving dangerous animals, remote or extreme locations, or high-risk equipment/ methods). Follow legal and permit requirements including human and animal ethics approvals. Include safety risk considerations in the planning stage of projects. Brief participants on risks and monitor volunteer health. Follow volunteer management requirements including volunteer induction, supervision, and insurance. • Undertake a cost/benefit analysis for all proposed citizen science projects and delist those that fail to show a clear benefit to project objectives from the use of volunteers. • Ask volunteers to identify the days that they can commit to. Build resilience into the program, especially in project critical roles, by avoiding use of unreliable individuals, or deflecting them to other activities. • Provide clear communication about what is on offer and the likely benefits to participants. • Offer training for staff and access to guiding documents/resources to support effective communication with volunteers.

3.5 Other potential benefits

Citizen science projects potentially:

1. connect people to a place, the place they have helped to study, and therefore to its ongoing management
2. provide networks that can be used to disseminate information, seek feedback on policies, etc. In the United Kingdom, because of concerns about Bovine Spongiform Encephalopathy and genetically modified foods, citizen science is seen as a way of increasing dialogue between science, policy, and public opinion
3. provide access to additional and new sources of funding (e.g., crowd sourced, philanthropic) that would otherwise be less likely to be available to government and other agencies (e.g., Australian Native Orchid Society and DELWP collaborating to raise funds for native grassland orchid recovery via Pozible https://pozible.com/)
4. play a role in improving the quality of science by placing it under greater and wider scrutiny
5. add to the work satisfaction of scientists through the connections they make with members of the community
6. demonstrate a commitment to knowledge and data transparency by government

7. encourage the community to view supporting organisations in a positive light as a service provider giving access to scientific capabilities and empowering citizens to generate their own questions and seek answers.

4 Implementing a citizen science program to support 'Protecting Victoria's Environment – Biodiversity 2037'

This section discusses a wide range of issues relevant to implementing a citizen science program. It begins by summarising our key recommendations; then looks at the future context, through a vision, principles, and approach to behaviour change; before then considering potential components, projects, and advice.

4.1 Key recommendations

1. Identify the priority knowledge requirements to support biodiversity health and then look for contributions by citizen science

   The value of citizen science comes from the collection of valuable data that can inform management decisions to protect biodiversity. The 'trap' of finding highly practical citizen science projects that collect low priority data should be avoided. A multi-stakeholder process for identifying the critical knowledge gaps is a crucial first step toward implementing a citizen science program.

2. Integrate behaviour change expertise and social science into program design

   'There is now an emerging recognition that environmental problems, while starting with a natural science base, are largely caused by human beings, affect human beings and need to be resolved by human action. In other words, they essentially involve the social sciences'. (Harris 1998, in Aitken 1999)

   The 'human side' of managing biodiversity is recognised as one of the two goals of 'Protecting Victoria's Environment – Biodiversity 2037'. Integration of the expertise of those who understand how to change human behaviour is important for implementation of the plan and no less to the citizen science component of the plan. Behaviour change is a science with an extensive literature and knowledge largely derived from its interest to commercial business. Behaviour change scientists should be engaged in program design from the outset and should provide advice on how to achieve the behaviour change goals of the Plan.

3. Work with partners in the citizen science sector

   There is a large body of capability and expertise already in existence with links to many current volunteers who could be engaged in delivering citizen science projects. There is an opportunity to drive increased collective impact by connecting the sector and activities that contribute the most to delivery of biodiversity priorities.

4. Evaluate the program experimentally to determine whether behaviour change has met 'Protecting Victoria's Environment – Biodiversity 2037' expectations

A thorough, scientifically valid evaluation will underscore the contribution of citizen science. Without it, there will be inadequate evidence on the role of citizen science, versus other factors, in achieving progress.

This section considers the practical issues relating to design and implementation of a citizen science program within the context of the objectives of 'Protecting Victoria's Environment – Biodiversity 2037'. A vision and principles are described that could form the future basis of discussions among the sectors. Potential benefits, risks and controls are then considered to identify components of an effective program.

4.2 Defining citizen science

A working definition of citizen science is:

> Volunteer citizens collaborating with scientists to enhance knowledge, and support management, of Victoria's biodiversity.

Such activities can offer excellent opportunities for connecting with nature.

4.3 Vision for citizen science

A vision for citizen science's contribution to 'Protecting Victoria's Environment – Biodiversity 2037' is:

- citizen science projects (including volunteer generated projects) across the sector increasingly focussed on 'Protecting Victoria's Environment – Biodiversity 2037' knowledge priorities
- valuable research being undertaken and associated with this, high quality data collected and submitted by citizen scientists
- a vibrant and effective citizen science sector
- organisations empowered and supported to pursue citizen science approaches
- appropriate governance, support, leadership, resources, staffing and infrastructure (including technology platforms) in place to deliver projects involving citizen scientists
- volunteer groups being supported with advice on how to design and implement scientifically valid citizen science projects
- improved biodiversity outcomes because of citizen science's contributions, including those informing decision-making, particularly in areas of high priority for biodiversity
- citizen science projects connecting Victorians with nature and contributing to their wellbeing.

'Protecting Victoria's Environment – Biodiversity 2037' (DELWP 2017) envisages citizen science playing a role in 'Linking opportunities for people to connect with nature to on-ground biodiversity management needs' (p15), 'contributing knowledge and information' (p22) and 'increasing people's awareness and understanding of the environment' (p24).

4.4 Principles of citizen science

The following broad principles of citizen science are adopted in this report. They are modified from the 10 principles adopted by the European Citizen Science Association (see Appendix 1 for more detail).

Citizen science should be:

- **best fit** – use of a citizen science approach is optional (a science project is not always compatible with the use of volunteers; costs may exceed gains)
- **meaningful** – generates specific knowledge of value (not undertaken as an end in itself)
- **rigorous** – has genuine experimental design and outcomes (is valid and can withstand critique); biases of using volunteers are controlled for; projects are evaluated
- **equitable** – scientists and volunteers benefit; citizen scientists are acknowledged
- **open** – participation is potentially open at all levels of the scientific process (the various levels of skills of volunteers are acknowledged)
- **communicative** – feedback is provided (two-way exchange)
- **transparent** – data are made publicly available
- **ethical** – safety, legal and ethical issues are managed.

Related principles of Protecting Victoria's Environment – Biodiversity 2037

'Protecting Victoria's Environment – Biodiversity 2037' principles (p8) that particularly relate to citizen science include:

- citizens and communities are engaged in decisions that affect them
- multiple sources of knowledge are recognised, freely shared, and used as a foundation for decision-making
- the limitations and uncertainties of available knowledge are acknowledged, while the knowledge base is continually improved.

4.5 Changing people's behaviours

'Protecting Victoria's Environment – Biodiversity 2037' envisages people valuing nature and thereby acting to protect it. This may involve a range of behaviours that benefit nature directly (e.g., giving time and volunteering, land use, pet management, wildlife gardening) or indirectly (e.g., reducing carbon footprint, advocacy, investing/funding).

A citizen science program needs to define the behavioural outcomes it seeks. These may be simple, such as recruiting more people as citizen scientists, or more complex involving those citizens changing their behaviours, or those of others, as described above.

Changing human behaviour is complex (Steg and Vlek 2009; Boulet 2016; CSIRO 2016,). Behaviour change is a specialist field with considerable theoretical underpinnings that can guide project and program design.

The Theory of Planned Behaviour (TPB) 'is one of the most widely used theories for understanding human behaviour' (Martin et al. 2016b). It requires an understanding of intentions, which are a strong predictor of future behaviour, beliefs, attitudes, perceived norms, and behavioural controls (i.e., how easy the task is for the participant to perform). The theory has been used by Zoos Victoria to design its campaigns (e.g., Palm Oil, Safe Cat Safe Wildlife) (Liam Smith, BehaviourWorks pers. comm.).

According to TPB, behavioural outcomes should be defined in terms of four key elements: action, target, context, and time. For example: a person *logging* (action) a *sighting* (target) of an *uncommon species* (context) *sometime in the next 12 months* (time). More information on TPB is contained in Martin et al. (2016b) and prime sources.

In a study of zoo visitors, Smith et al. (2010) found that four factors were important in requests for behaviour change: **simplicity** (e.g., the behaviour could be done on site), **efficacy** (is linked to the issue), **newness** (novel messages and actions) and **how the behaviour was promoted** (persuasive but not 'in-your-face' or guilt-laden).

Craig Cormick (CSIRO, 2016), observed that behaviours are most influenced by:

- social norms (attitudes and behaviours of peers)
- 'nudging' (incremental small changes)
- incentives to adopt a new behaviour (attitudes follow)
- training programs from trusted sources.

Successful approaches to using citizen science for behaviour change will therefore:

- clearly define the behaviour change being sought
- use behaviour change theory/expertise in their design
- be relatively simple, efficacious, novel and rewarding
- seek to establish the desired social norms (see Appendix 11 for examples of behaviour change models).

4.6 Potential components of an implementation plan

Government component – government-led projects based on 'Protecting Victoria's Environment – Biodiversity 2037' priorities.

This component would address research priorities identified under ‘Protecting Victoria’s Environment – Biodiversity 2037’. A lead scientist would design the project, potentially with partner organisations. Volunteers would be recruited to participate in identified roles. A small number of projects could be selected that have a high knowledge yield AND strong benefits for volunteers. Existing research projects that could benefit from a citizen science component should be considered.

Community component – community helping to implement ‘Protecting Victoria’s Environment – Biodiversity 2037’.

Government would support community-driven science projects via commissioned projects and grants that meet criteria for alignment with ‘Protecting Victoria’s Environment – Biodiversity 2037’ through:

1. Science hubs – creating a location where free assistance with developing a citizen science project on biodiversity was readily available.

   There could be:

   - seminars on scientific methods applied to biodiversity
   - volunteer scientists and government scientists made available for one-on-one consultations with advice on design, statistical analysis, and data interpretation
   - assistance with applying for permits required by legislation
   - hosted events for community to meet citizen science providers
   - hosted events to showcase the range of tools and resources available (e.g., Victorian Biodiversity Atlas, Atlas of Living Australia, iNaturalist)
   - reference materials made available at a range of city and country locations (e.g., local environment centres).

2. Community citizen science projects that align with ‘Protecting Victoria’s Environment – Biodiversity 2037’
   - Grants for projects
   - Equipment loan/gift scheme
   - Training (e.g., in safety and use of equipment and data collection in the field)

3. Reward and recognition – of outstanding projects or individuals.

Expert/university component – connecting with experts and scientists in training

- Co-designed projects with university staff and volunteer students to meet ‘Protecting Victoria’s Environment – Biodiversity 2037’ priorities
- Training in field science by university/government scientists
- Liaison with government and the policy process
- Incentives for experts (e.g., retired biologists, consultants) to collect high value data (reverse auction/fuel subsidies?)
- Incentives for experts to undertake support roles (e.g., as data reviewers, project designers, species identifiers)

CS Sector component – strengthening the citizen science sector

- Regular network meetings – develop a community of practice
- Brokering gatherings where potential volunteers and technology providers can meet projects
- Supporting the development of a portal for Victoria to link projects to volunteers. This could link to the Victorian Government volunteering website. It would depend on citizen science sector support.

Business/philanthropic component

- Encouraging sponsorship of citizen scientist projects (outside government)
- Donation of equipment, prizes to citizens by corporations/philanthropists
- Opportunities for corporate staff participation in citizen science.

Governance and Infrastructure component

- Coordination – appointing coordinators
- Portal – to access information
- Technology/Apps
- Volunteer network management.

Communication and evaluation component

- Promotion of a citizen science program
- Training materials and venues
- Evaluating the success of the program.

4.7 Project identification and design

A good citizen science project has a clear objective and is appealing to both investors, for the biodiversity and social outcomes they seek, and to volunteers for the contribution, learning, socializing and enjoyment they desire. It has meaningful outcomes in the eyes of both investors and volunteers.

Citizen science can be a good choice when projects involve data collection:

- requiring a large number of people
- over large areas, including private land
- over long time periods
- at unusual times (e.g., non-working hours)
- at a fixed location at regular intervals (ideally local to volunteers)
- contain relatively simple and safe procedures
- at low cost (time, funds) to the investor
- where specialist equipment (e.g., SCUBA gear, photographic equipment) can be provided by citizens.

See Appendix 6a for a decision framework on when to use citizen science.

For citizens, citizen science is an attractive option when:

- it is interesting and meaningful (for some; educational)
- it fits within time, cost, and physical constraints
- it is well managed with time to socialise
- efforts are valued and recognised
- there is regular feedback on the broader program including how information is used.

4.8 Implementation schedule

The following checklist is provided to assist with development of an implementation plan for a citizen science program in Victoria. Some components can occur concurrently.

Online resources are also available:

- A ‘how to’ toolkit can be found at: https://crowdsourcing-toolkit.sites.usa.gov/howto/ or for a simple set of steps http://www.birds.cornell.edu/citscitoolkit/toolkit/steps/steps.
- Practical guidelines for developing a Bioblitz can be found at: http://www.thenatureofcities.com/2015/03/01/citizen-science-in-the-city-lessons-from-melbournes-bioblitz/.

Implementation items

1. **Understand the authorising environment (i.e., the alignment with organisational priorities).** Points to consider include:
    - clarifying the authorising environment. Is a public policy/position statement useful? (as in NSW: https://www.environment.nsw.gov.au/research-and-publications/your-research/citizen-science)
    - the funding and scale of a citizen science program
    - legal, ethical (human and animal), safety and insurance issues relating to the use of volunteers
    - scientist and policymaker acceptance of the validity of citizen science
    - appetite for levels of engagement and risk – co-design, empowerment (relevant risk management frameworks).
2. **Establish governance and networks**

    A governance framework needs to consider:
    - leadership – who is the senior responsible officer for citizen science projects undertaken or sponsored
    - the program steering committee
    - the relationship between citizen science governance and related governance frameworks including Biodiversity Response Planning/Biodiversity Forums as envisaged in 'Protecting Victoria's Environment – Biodiversity 2037'
    - appointing coordinator(s) (see Appendix 4 for attributes) and staff
    - establishing a community of interest
    - engaging with citizen science networks/developing partnerships
    - data sharing arrangements
    - engaging with communications staff and developing a program communication plan (see below)
    - initiating the program evaluation plan (see Section 4.19 for more on how programs can be evaluated experimentally)
3. **Generate project ideas/encourage innovation**

Identifying the projects that will make the most useful contribution to knowledge and are amenable to a citizen science approach is a critical step. Points to consider include:

- the knowledge requirements of 'Protecting Victoria's Environment – Biodiversity 2037' including listing potential projects in priority order with why they are important and how the data will be used (see 'What makes a good citizen science project?' **Error! Bookmark not defined.**)
- generating innovative ideas – tapping in to innovative/creative thinkers
- options for joint or collaborative development and citizen-initiated project ideas
- encouraging others to develop ideas and submit them – promotion, incentives, prizes etc.

There is wide scope to be innovative in developing citizen science. For example, smart phone technology could deliver to participants the highest value knowledge requirements for the location they are currently at while also being tailored to their level of skill. It could pre-fill components of their data recording app and provide instantaneous feedback about the value of the data collected in formats that suit the user. Species identification could be by image or sound recognition software supported by the volunteer's own thoughts.

Use innovation principles to design an appropriate process. Many articles on innovation principles and pillars are available online.

4. **Screening**

Not all projects are suited to citizen science. Selection of projects for their alignment with citizen science involves:

- screening – is citizen science the appropriate approach? Does it align with ‘Protecting Victoria’s Environment – Biodiversity 2037’ priorities? Does benefit exceed cost? (see Appendix 6 for a framework to help assess whether citizen science is appropriate)
- considering the level of scientific expertise required and available via potential participants.
- considering the delivery agent — citizen science sector versus ‘in house’/’in partnership‘
- assessing whether adequate funding is available.

Unfunded or partially-funded project ideas could be submitted for inclusion in the ‘Investment Prospectus’ envisaged by ‘Protecting Victoria’s Environment – Biodiversity 2037’ and to other potential sources of funds (e.g., crowd funding sites, philanthropic organisations).

5. **Develop detailed project plans**

   Project planning involves:

   - clearly defining the objective. Is it primarily biological/ ecological or social?
   - being clear about the question(s) under investigation
   - project governance
   - resourcing – where are the resources coming from?
   - project design (this should be undertaken by an experienced scientist with appropriate peer review and biometric advice [see Appendix 6 for a best practice framework for projects])
   - identifying the data to be collected, its value and use
   - audience – what is the appropriate volunteer audience for this project (adult/student, experienced/inexperienced, short term/long term, location, skill/interest)
   - clarifying privacy, copyright, intellectual property, data sharing agreements, data sensitivity, confidentiality, attribution, and the environmental impact of any activities
   - obtaining permits/licenses/approvals/ethics (see ‘Legislation and permits’ below)
   - identifying project milestones
   - developing a project communication plan
   - developing a project Theory of Change and Evaluation Plan – how will the project be evaluated?
   - developing a COVID-19 Safety, general safety, and cultural safety (if relevant) Plan
   - clarifying the project termination point; having a clear exit plan.

6. **Identify or create the infrastructure**

   Infrastructure and logistics components include:

   - the equipment required for the project
   - infrastructure partners and their requirements
   - technology platforms – can existing platforms be used or be modified? Are new platforms needed?
   - data collection protocols/templates – refining protocols for data accuracy, data for project and evaluation
   - data ownership, integrity, storage, and access
   - data analysis, display, feedback, and reporting – see Appendix 5 for a list of data collection and display options and check the web links in Appendices 2 and 9 for how existing projects have solved this issue.

7. **Recruit and manage volunteers and scientists**

   This step needs to be undertaken very carefully to ensure the right people are matched to projects. It includes:

   - consideration of whether a volunteer portal is needed and registration requirements (web/app-based)
   - understanding any barriers to participation and reducing them

- the needs of Culturally and Linguistically Diverse (CALD) communities/groups
- physical, psychological and cultural safety
- comprehensive, targeted media promotion via media releases, websites, social media, competitions, and partnerships with community groups (see Appendix 7 for a list of potential target audiences)
- motivating people/sectors with experience to offer
- background checks if necessary (e.g., police, Working with Children if relevant)
- matching skills to tasks
- assessing suitability, potentially via interviews, and directing people to appropriate opportunities
- paperwork/ administration (copyright, privacy, disclaimer etc.)
- project champions
- experimental designers, expert reviewers, biometricians, data managers, data analysts etc.
- training and education – introductory, basic skills, advanced skills
- maintaining volunteer interest
- reward and recognition – through a range of processes. Could include e.g., Premier's Volunteers Champions Awards.

8. **Deliver projects**

   Project delivery includes careful management of:

   - participant OHS and supervision
   - briefings (safety, communications, etc.)
   - data validation and auditing
   - data analysis
   - publishing results – where, how, timelines, authorisation
   - communication – feedback/reward and recognition/celebrating achievements.

9. **Communication**

Communication should occur throughout the project and ideally be managed via a communication plan that identifies goals, key stakeholders, messages, desired behaviours, what effective contributions look like, the appropriate delivery method and responsibilities. The level of engagement (i.e., passive participant to fully empowered) should be considered and clearly communicated to potential volunteers. Volunteer buy-in will generally be higher if they have more 'say' and ownership in a project.

Some volunteers will already be interested in citizen science opportunities or are participants in citizen science looking for new opportunities. Attracting new participants will likely require a sustained effort. Cultural and linguistic diversity will need to be considered.

Data on 'How people learnt about *Land for Wildlife*', a Victorian government scheme supporting private landholders protecting biodiversity, suggest that multiple exposures to an opportunity (several) are required before people act (i.e., sign up as a member of *Land for Wildlife*).

Communication should be transparent regarding project objectives, what citizens can expect and the capacity of data/science to influence policy outcomes. Participants need to understand what level of prior knowledge is required and their time commitment. To explain what is involved for volunteers, the use of existing participant stories is recommended (Martin et al. 2016b).

Communication can address beliefs and belief differences (see Martin et al. 2016b).

The use of event management systems or companies may be appropriate where large numbers of participants are involved in an event (e.g., Melbourne Bioblitz), and many other activities use Eventbrite – an online set of tools for creating and managing an event. The latter is free for free events.

'The (Melbourne) BioBlitz employed a variety of methods to facilitate citizen participation, from expert led surveys and activities to a variety of online tools including Bowerbird (formerly an interactive biodiversity data repository, now housed within the iNaturalist platform: https://www.inaturalist.org/projects/bowerbird),

Instagram, Twitter, and the City of Melbourne's own website. The preferred method for data capture during the BioBlitz turned out to be handwritten sightings, with over 750 sightings submitted in this format. Submissions to Participate Melbourne and Bowerbird closely followed the tally from handwritten sightings, with 744 and 739 uploads, respectively. Participants used Instagram and Twitter to a much lesser extent; participants used Twitter primarily to promote the BioBlitz rather than to record sightings.' http://www.thenatureofcities.com/2015/03/01/citizen-science-in-the-city-lessons-from-melbournes-bioblitz/

Platforms such as SWIFFT and iNaturalist enable projects and participants to communicate with large audiences.

10. **Project evaluation**

Evaluation should occur throughout the project lifecycle and should connect data gathered to the project objectives and any standard output data required by 'Protecting Victoria's Environment – Biodiversity 2037' MER framework.

Evaluation should incorporate volunteer feedback and assess changes in volunteer attitudes, knowledge, and behaviour (because of participating in the project).

Evaluation of outcomes is frequently constrained by the timeline for projects versus the timeline for outcomes to appear. One option here may be for the program to establish the baseline components of longitudinal studies of human behaviour and biodiversity health with partner institutions, such as the universities, where they might be pursued over time.

Cornell labs have given considerable thought to evaluation of citizen science projects. See Research and Evaluation Resources and Users Guide for Evaluating Learning Outcomes from Citizen Science

It may be better to pool evaluation resources and sample across all projects rather than to split them and evaluate at the project level.

See also 'Program evaluation' (Section 4.19) and Appendix 8 for sample evaluation frameworks.

'Protecting Victoria's Environment – Biodiversity 2037' will likely require standard output data to be collected.

11. **Project termination (or transition)**

Project Control Boards will need to consider how and when to terminate a project.

Volunteers should be aware of the project timeframe from the outset and regularly reminded as the end date approaches. Opportunities for ongoing involvement in other projects should be communicated.

Volunteers may be concerned about losing social connections made during the project. Options for staying connected (e.g., Facebook groups) could be discussed with them.

Projects may take on an independent life fully organised by volunteers. Long-term projects have been some of the most valuable in terms of providing authoritative data for management decisions because they can lead to high levels of statistical confidence and are appropriate to measure change across ecological timeframes. In appropriate circumstances, they should be encouraged and potential 'champions' nurtured.

4.9 Practical tips

The following tips are offered to help guide development of an implementation plan. They are general in nature and may not be appropriate to a particular circumstance.

Practical tips to guide program implementation

- Know what information/knowledge is required to protect biodiversity, and why, by preparing a knowledge strategy linked to 'Protecting Victoria's Environment – Biodiversity 2037'.
- Identify research priorities under 'Protecting Victoria's Environment – Biodiversity 2037' first, and then consider whether citizen science is an appropriate delivery method.
- Utilize principles of innovation and involve innovative people in generating project ideas.
- Start with the 'low hanging fruit' – projects needing data that have a direct link to important policy and management issues but that are also appealing to volunteers.
- Pilot projects to test their efficacy before launching into full scale deployment.
- Take care to pick the right coordinator — an enthusiastic person with the right mix of skills that can gain the confidence of the scientists, citizen science participants and volunteer community. See Appendix 4 for a list of coordinator attributes.

- Structure funding to allow for infrastructure development so that participants have positive experiences and data are easily and accurately captured.
- Support the sector, as a healthy sector will assist a program.
- Develop partnerships with relevant groups. Involve Traditional Owners as genuine partners early. Consider cultural safety and Indigenous Data implications. Interact with partners' networks and communication opportunities..
- Consider linking citizen science projects to land managers seeking answers to specific management questions.
- Consider the EPA model of using a project selection/endorsement process involving community representatives.
- When considering funding external partnerships, identify the 'champion(s)' whose enthusiasm will drive the project over time.
- Work closely with the public institutions with a high public interface (Zoos Victoria, Museum Victoria, Parks Victoria, art galleries – the biodiversity 'shopfronts') – on promoting citizen science opportunities in 'Protecting

Victoria's Environment – Biodiversity 2037'.

- Consult early, and often with partners.
- Consider developing a portal to opportunities across the sector. This could take advantage of what already exists and support the sector.
- Train the trainer to expand the network of people with skills in supporting others.
- Think about Cultural and Linguistic Diversity and its relevance to achieving your program objectives. How can CALD people be included? Support leadership by CALD sector.
- Broker events at which potential volunteers are introduced to existing citizen science projects and, separately, at which providers are introduced to technology platform providers and training.

12. Look at data exchange agreements as a way of accessing valuable data.
13. Consider the potential for digitising existing data, such as historical field notes and images.
14. Consider the potential for adding data into VBA Go or creating wiki sites and seeking community input to complete/add.
15. Name projects to appeal to an audience. Avoid the

term ‘citizen science’. Terms such as ‘nature’ and ‘wildlife’ have wider recognition and appeal.

16. Practice deep listening to the conversation of volunteers to keep in touch with their needs.
17. Communicate via numerous channels as not all volunteers are connected to a peak body or group.
18. Provide feedback loops to ensure the value of the knowledge gained is made evident to participants.
19. Invest into a long-term network of volunteers (versus short-term approaches). During their initial assignment, volunteers could be asked to nominate their interest in being a long-term participant.
20. To gain support for the value of the program internally, promote the wins for biodiversity and participants (e.g., Yammer, email bulletins) and externally (email alerts, website, networks, social media).
21. Consider using volunteers to help promote opportunities via social media.
22. Involve key people via reward and recognition events, grant announcements etc. across the whole sector.
23. Provide incentives to those with high levels of science capability,

such as retired scientists and biological consultants, to address knowledge gaps. Offers of incentives such as free national park camping, transport, fuel subsidies, social events, or reimbursement of expenses, might be appropriate in some circumstances and may be cost effective.

4.10 Principles and criteria for government investment in citizen science

The following principles and criteria are provided to assist organisations considering investment in citizen science. The principles aim to support and strengthen the existing citizen science sector and avoid duplication of effort. A simple framework for assessing the relative value of projects is provided as an example of how to review and rank the contribution each proposal could make to the objectives of 'Protecting Victoria's Environment – Biodiversity 2037' and project viability.

Principles

- **Community benefit** – there should be a clear benefit to the Victorian community and, in particular, delivery of 'Protecting Victoria's Environment – Biodiversity 2037' for Victoria.
- **Gaps** – government should invest where there is no current provider (i.e., not enter into competition with existing services). In some cases, a partnership with another provider may prove to be the most cost-effective approach. Government investment may assist other providers to establish where this meets its objectives (e.g., Royal Botanic Gardens support for Fungimap allowed it to grow until it could operate largely independently).
- **Cost/benefit** – taking account of all benefits including people valuing nature, citizen science should be less costly than alternatives.
- **Evaluation** - programs should be monitored and evaluated; government can provide common evaluation metrics and guidance.

Given that there are many established providers of citizen science, and the recent development of peak bodies, government may be best to position itself as a supporter of the sector and programs that align with government priorities. Where the 'market' does not provide the outcomes, then there is a case for government to develop these, through building the capacity of others or direct investment.

For example, Gardiner et al. (2012) found that use of citizen scientists in the UK for a lady beetle study was more cost effective than traditional science in terms of data gathered per dollar.

Criteria for assessing project proposals

- **Value** to implementing 'Protecting Victoria's Environment – Biodiversity 2037' of the knowledge to be gained and value to the organisation of the engagement and networks that result from using citizen science. Projects that address critical knowledge gaps (i.e., those where the knowledge is important to decision-making, current confidence is low and could be significantly improved) would have the highest value.
- **Likelihood of success (risk)** of the project in meeting its objectives, including capacity of participants to carry out the project and assessing project risks, and benefit/cost assessment of using citizen science.
- The **practicality** of delivering the project.

Scale and duration

Program design will need to consider the best combination of large/small scale projects, over long-term or short-term durations.

The decision about the scale and length of the program should be driven by the research design and the amount of data needed to be confident of any inferences made from it.

Long-term monitoring is often required to reveal the underlying patterns in ecological systems.

The scale of the investment program is also relevant. Coordination and infrastructure costs can be significant and will impact on a smaller-scale investment more than a larger one. Large-scale projects often require high levels of coordination. Using a part-time (or sharing a) coordinator might help to contain coordination costs. Co-investment in infrastructure with others might likewise reduce the impact this has on program resources.

The time it takes to recruit and train volunteer citizen scientists can be significant. Hence, consideration needs to be given to maintaining involvement of volunteers over long periods of time. Building the infrastructure to recruit and manage volunteers within the citizen science sector is preferable to one-off approaches.

‘Wildlife Spotter’ statistics

https://wildlifespotter.net.au/

Wildlife spotter is an online citizen science project that allows citizens to analyse remote camera images taken in rural and urban environments. By allowing people to contribute from a location (e.g., home, office, school), and at a time of their choice, large-scale participation was achieved. Data are from the Wildlife Spotter website in 2016.

- Around 48,000 citizen scientists did 29,000 hours of work
- Equivalent to one person working a 40-hour week for 15 years (with 4 weeks holiday a year)
- 7,525 individuals
- 4,246 guests (unregistered but participating)
- 339 school groups, comprising 36,109 students
- Over two million wildlife camera trap images classified
- 6 projects from across Australia
- 2,168,566 images classified
- 800,000 unique images
- One person did 19,082 images
- One school group processed 14,550 images.

It is more difficult to sustain a team of citizen scientists over time, but there are many examples of this being achieved (e.g., Sherbrooke Lyrebird Survey, Victorian Wader Study Group, Fungimap). Important factors include: a ‘champion(s)’ who is passionate about the project, ongoing value being derived from additional data collection, and an appropriate balance between maintaining the project and enjoying being part of it as a volunteer. A significant advantage of building a long-term network is the reduced transaction costs in recruitment and training of volunteers. As government priorities change, consideration should be given to building community capacity to remain active in citizen science well beyond project timeframes. For example, equipping a ‘Friends’ group and linking them to a science body may allow the group to collect valuable data for many years.

Achieving large-scale participation

- Most citizen science projects are relatively small-scale. If the aim is to reach large numbers of people, then the citizen science project must be designed appropriately. Successful large-scale projects, for example Cornell Laboratory of Ornithology’s eBird, FrogID, Birdlife Australia’s bird atlas data, Aussie Backyard Bird Count and Wildlife Spotter (see breakout box), have achieved mass appeal (tens of thousands of people).

Characteristics of these programs include:

- A champion to nurture the program and provide the drive that ensures continuity
- A focus on species/subjects already of interest to the volunteer
- The use of technology to create a user-friendly interface, with apps to manage data acquisition, and providing continuous feedback to participants (e.g., on number of volunteers, sightings)
- Well managed communication/promotion. In the case of Wildlife Spotter, the ABC was a partner therefore providing extensive media coverage
- Ongoing participation to build the number of volunteer recruits
- Independent of government/formally constituted organisations, not-for-profit.

Large audiences will be found in cities and regional centres, so citizen science projects that are relevant to these situations are more likely to be adopted *en masse*. ‘The Melbourne BioBlitz was conducted over 15 days from 31 October to 14 November 2014. During that time, more than 700 citizens participated in the initiative, collecting over 3,000 biodiversity records for the city. Of those 3,000 records, 600 sightings were identified to species or genus level and 500 different species were identified by common names. Groups of taxa identified included insects, mammals, reptiles, birds, plants, fungi, and aquatic life. Invertebrates and birds together accounted for 90 percent of all sightings across the municipality.’ http://www.thenatureofcities.com/2015/03/01/citizen-science-in-the-city-lessons-from-melbournes-bioblitz/

Focusing on backyard species, especially birds, is a common approach in urban environments (e.g., BirdLife Australia). Projects that respond to time-poor, tech savvy individuals are also likely to achieve wider adoption as data can be entered at home/on the way to work/at lunch and in a short timeframe. An OEH survey (OEH 2016) found that most potential volunteers preferred ‘entering data from paper sources’ and ‘looking at photos and classifying them’. ‘Taking regular measurements in a local place’ was also more appealing.

The zoo, museum and art gallery are large public institutions with high levels of visitation that could be leveraged to create biodiversity 'shopfronts' to assist in promoting citizen science, recruiting volunteers, and helping achieve desired behaviour change.

The bird watching, gardening, and fishing communities contain large numbers of potential recruits (see Appendix 7 for potential volunteer sources).

It is unlikely that people who have had a relatively cursory interaction with citizen science will be inspired to change long held behaviours; longer term participation is more likely to yield desirable behaviour change.

4.11 Access to technical support and resources

Government investment in citizen science could include a component that supports citizen science groups via providing free or subsidised access to technical support and resources.

Support provided could include:

- advice from professional scientists (government, willing retirees) on project design, analysis, and interpretation of results
- protocols and training
- data collection equipment (e.g., cameras, traps, computers, GPS, maps)
- transport (vehicles, transport subsidies)
- meeting facilities/accommodation
- reference material (e.g., field guides).

4.12 Motivating volunteers

It is important that leaders 'step into the shoes' of the volunteer to understand what motivates them as an individual and as a volunteer. Induction processes could include collecting data about what volunteers aim to get out of their involvement in citizen science.

Important elements in motivating volunteers include:

- a direct invitation
- convenient scheduling (to fit in with other elements of life)
- meaningful outcomes (to the volunteer) and demonstration of how they can/did make a difference
- positive feedback
- opportunity for new experiences
- positive relationships – social networks, time to get to know other people
- Enjoyment/fun – e.g., time out from project work to socialise/laugh
- Barriers to participation addressed to the extent possible
- Good leadership – inclusive, accessible, respectful, regular meetings, listening, grievance processes
- Reward and recognition (e.g., thanks, training, food, peer/social recognition, conference attendance, length-of-service pins, uniform, certificates).

Useful websites on motivating volunteers are listed below:

http://www.volunteerpower.com/articles/motivate.asp

https://www.environment.vic.gov.au/volunteering

http://able-altruist.softwareadvice.com/what-motivates-people-to-become-repeat-volunteers-0614/

4.13 Training

A perception by potential volunteers that they have insufficient knowledge to contribute is a major barrier to participation in citizen science (Martin et al. 2016b).

Training is an essential adjunct to any citizen science project. It should build confidence in participants that they can contribute, encourage social networks to form, and address issues of data quality. It is important that projects clearly communicate the level of baseline knowledge required to participate before entering training.

Training is a specialist activity that is ideally delivered by a qualified trainer/teacher. Professional scientists may or may not have the ability to conduct training. In any case, it is potentially a distraction from their main contribution of scientific oversight and input. Training options should be assessed carefully.

Online courses and videos (e.g., YouTube) offer a means to train and test participants who are unable to attend a training venue, and also offer additional forms of learning and the potential for 'refresher' or follow-up learning. These methods of delivery allow a degree of quality control over what is delivered, but lack the face-to-face interaction with a trainer that can reveal issues of concern to the trainee, and which enable the development of good program partnership relationships.

4.14 Responding to constraints on participation

'Protecting Victoria's Environment – Biodiversity 2037' (p12) recognises that 'to get more people engaged with nature and acting to protect biodiversity, we need to better understand the barriers to community involvement – and the opportunities to be involved'.

There are numerous factors that work against participation in citizen science projects. They include:

- **awareness** – three quarters of people surveyed in NSW could not name an organisation that supported citizen science (OEH 2016)
- **self-doubt** – of potential volunteers about whether they have the skills and prior knowledge to contribute to a 'science' project (Martin et al. 2016). Many potential volunteers did not do well in school science, have low esteem about their ability to contribute as adults, and may have a relatively narrow definition of science
- **time and other priorities** – many potential volunteers have little time to give and consider themselves too busy. They prefer short duration contributions that they are passionate about and that can be done locally or at home, including online (OEH 2016)
- **professional scientist availability** – the number and available time of scientists to design and supervise projects
- **perceptions of unreliable data** – A 2014 survey of 122 citizen science project leaders found that, after funding, 'perception of unreliable data' was ranked as the second major barrier to successfully conducting citizen science projects (Pecl et al. 2015)
- **project location** – the location and type of priority projects (distance from volunteer networks)
- **project resources** – the resource requirements can place constraints on the number of people involved as they limit the capacity for supervision and support of volunteers
- **weather** – can affect attendance at outdoor events and commitment to activities
- **health** – participants with the most time available (older, people with disabilities) may have activity limitations.

Responses to these issues could include:

- effective promotion of citizen science sector opportunities to target audiences
- clarity in the information provided around the range of tasks involved
- consideration of the language used (e.g., 'citizen' and 'science' may deter some people and other terms may be more useful and engaging)
- short 'introduction to citizen science' sessions for novices to address concerns about what is involved
- stepped involvement, with greater experience leading to the next stage

- targeting individuals with more time available such as retirees, unemployed, students, people on holiday/travellers
- encouraging volunteers to ‘bring a friend’, tell others about their participation
- organising activities at weekends or out of business hours
- offering activities that include a range of time requirements, including requiring only a short amount of time
- including government scientist availability in staff performance plans, funding this activity, and providing access to a range of supporting resources
- establishing data collection protocols and auditing processes, assessing data for bias
- offering subsidised transport to remote sites and/or accommodation
- matching volunteers to the tasks they are capable of performing.

4.15 Resolving tensions

A number of tensions exist within citizen science, as within any complex activity. They are outlined below.

Community priorities versus ‘Protecting Victoria’s Environment – Biodiversity 2037’ priorities

Giving citizens the opportunity to create or co-create projects of relevance to them can be an important factor in their participation. However, this may come at the expense of priority in ‘Protecting Victoria’s Environment – Biodiversity 2037’. Commissioning projects can be an efficient way to ensure that priority projects are funded, but seeking bids and providing grants is more likely to result in citizen ‘buy-in’.

This issue may be resolved by:

- clearly communicating ‘Protecting Victoria’s Environment – Biodiversity 2037’ priorities
- working with potential participants to identify alignments between their priorities and those of ‘Protecting Victoria’s Environment – Biodiversity 2037’ (potentially via Biodiversity Response Planning processes)
- offering support to both community-initiated and ‘Protecting Victoria’s Environment – Biodiversity 2037’-driven priorities via a mix of commissioned projects and grants, the latter being required to show links to biodiversity priorities.

Biodiversity versus social goals

The design of a citizen science project is affected by whether the primary purpose is driven by a biodiversity or social goal. For example, if the aim is to engage large numbers of people across a large area, then the design will: (1) need to appeal to a wide audience; (2) need to cater for management of the numbers; (3) tend to require simplification of techniques and data, less direct training and scientific supervision; and (4) need more sophisticated online technology. At this scale and level of interaction, social objectives relating to behaviour change may be difficult to achieve. The priorities for ‘Protecting Victoria’s Environment – Biodiversity 2037’, which may not immediately appeal to a wide audience, could be even more difficult to address.

This issue may be resolved by:

- being very clear about the objectives of a project at the outset
- being realistic about what citizen science can achieve
- targeting volunteers appropriate to a project
- knowing which ‘Protecting Victoria’s Environment – Biodiversity 2037’ priority projects have potential to have wide appeal.

Project milestones versus volunteer commitment and contentment

Projects are developed around a specific budget, milestones, and end date. Working with volunteers can be unpredictable and some individuals can have varying availability, unable to commit to specific timelines or in need of more flexibility than the project can manage.

This issue may be resolved by:

- informing participants about the level of commitment required and allowing self-selection
- building time resilience into project planning
- breaking tasks into smaller modules
- placing paid staff into time-critical roles
- advising volunteers of the project duration and follow-on options.

Scientific versus other forms of knowledge

In some projects, there are powerful opportunities and strengths in considering and collating different forms of knowledge. In other projects, tension can occur between knowledge derived from scientific methods versus other methods due to difficulties in comparing knowledge types, particularly when they tell different stories.

'Protecting Victoria's Environment – Biodiversity 2037' specifically incorporates the principle that 'Multiple sources of knowledge (e.g., science-based, traditional, community), are recognised, and knowledge is freely shared and used as a common foundation for decision-making.' (DELWP 2017, p8).

This issue may be resolved by:

- acknowledging that there are multiple forms of knowledge recognised by organisations and the community
- being clear about where citizen science aims to generate data-driven, evidence-based scientific knowledge (almost all instances)
- informing participants that science is an important, but not the only, source of knowledge that is considered in decision-making. Other forms of knowledge may be given due weight in a decision.

Government versus citizen intellectual property

Data are a valuable resource. Data ownership and use can cause conflict.

Potential solutions are:

- to seek clear legal guidance and contemporary policy advice regarding intellectual property
- to clearly identify ownership of intellectual property and copyright in project agreements that is consistent with any relevant laws and policies
- for project participants, including volunteers, to agree on data sharing arrangements at the outset consistent with principles of justice and equity, and proportionate to the contribution being made
- for project participants to acknowledge that science and data are one of numerous inputs to government decision-making.

4.16 Legislation and permits

A range of legislation is relevant to citizen science including:

Environment Protection and Biodiversity Conservation Act 1999 – where a project may have an impact on matters of national environmental significance, national heritage, wetlands of international importance, listed threatened species and ecological communities, migratory species, or cetaceans. http://www.environment.gov.au/epbc/permits-and-application-forms

Flora and Fauna Guarantee Act 1988 – the taking (except for the purpose of controlling), trading in, keeping, moving, or processing of protected flora. https://www.environment.vic.gov.au/conserving-threatened-species/flora-and-fauna-guarantee-act-1988/protected-flora-controls

National Health and Medical Research Council Act 1992 – requires that all research 'involving or impacting on humans' conform to the National Statement on Ethical Conduct in Human Research (2007) and be assessed by a human research ethics committee.

National Parks Act 1975 – for approval to undertake research in a national park or marine sanctuary. https://www.environment.vic.gov.au/__data/assets/pdf_file/0016/50434/Application-for-Permit-to-Conduct-Research-in-National-Parks.pdf

Prevention of Cruelty to Animals Act 1986 – establishes animal ethics committees that assess the ethics of projects.

Privacy Act 1988 – regulates how personal information is handled.

Citizen science projects will need to obtain the necessary permits before activities can be undertaken.

DELWP could play a role in assisting groups wishing to undertake citizen science projects to navigate the approvals processes.

4.17 Data management

The type of data to be collected, its storage, retrieval, analysis, access, and display are all important issues to be considered when designing a citizen science program or project.

Data may take many forms. Citizen scientists can be involved in collecting new data through observation or measurement. Historical data is also a potentially rich resource that citizen scientists may be able to tap into (e.g., digitising field notebooks, searching for historical photographs in private collections, locating pubs with taxidermied Murray Cod). The form of data to be collected – visual, sound, smell, time, weight, breeding, migratory, etc. is an important consideration at the project level.

Data is the fundamental currency of science and failure to attend to data quality is one of the major reasons professional scientists express concerns about involving citizens in science. This issue can be addressed by choice of volunteer, training, methodology, validation checks during data entry and audits for data quality. In some cases, the demands exceed what can be expected of a citizen scientist and should be left to trained professionals.

Data analysis can be complex and usually requires high level expertise both in the project design phase and once data is collected. The need for advice from a biometrician should be considered as part of project planning.

Data storage is also a significant issue. An appropriate data structure and associated metadata are needed to maintain the value of the data collected and allow its future retrieval and use. Expertise is often required and may need to be factored into project design and costing.

Access to data, and tools to aid its discovery such as mapping of sites where data was collected, are important considerations. The Victorian government's DataVic portal and data access policies are a useful starting point. See data.vic.gov.au

The power of citizen science to collect vast amounts of valuable ecological data is well illustrated by eBird, established by the Cornell Lab of Ornithology in 2002 to collect information on bird abundance and distribution. Through a combination of community engagement and partnerships, supported by modern communication tools, eBird has created a global network of volunteers who submit an average of three million observations per month (Sullivan 2014).

It is unclear how much current citizen science data reaches databases used by government or is used to influence important decisions for biodiversity conservation.

The Australian Wader Study Group shorebird monitoring data has been used to influence numerous planning and development proposals.

Citizen's data tends to be scattered among receiving data systems or may exist in field notebooks. Citizens tend to favour data input that they are most comfortable using. Improved data exchange offers considerable potential to increase the availability of data to all users.

The Victorian Government has a policy of making its data available – see data.vic.gov.au

4.18 Publishing

'New information does not become science until it is made social.' - E.O. Wilson.

Publishing the results of a citizen science study, as for any research project, has numerous benefits. It provides a source of information about the project beyond the life of participants and is feedback to volunteers involved in the project. Feedback (e.g., evidence of your data having been recorded) should be as immediate as possible. Reporting should be done as soon as practical following the end of a project. Collaborations with external partners may be beneficial in providing expedient publishing services. Publishing also enables research to become applied (and therefore more clearly meaningful). Consideration should be given to including citizen scientists in publication authorship where relevant.

Examples of project reporting can be found on the VNPA website e.g., http://vnpa.org.au/page/publications/reports/legging-it-for-lizards

4.19 Program evaluation

Program evaluation should be done experimentally and designed into the program from the outset. Ferraro and Pattanayak (2006) discuss state-of-the-art approaches to evaluating biodiversity programs using experimental (or quasi-experimental) design. For example, citizens could be selected, and their behaviours tracked following exposure, or not, to citizen science activity. The specific change in behaviours expected of participants in the program need to be identified. The experimental design will determine the numbers required for confident inferences to be drawn.

A program logic and Theory of Change can assist evaluation and should be developed with stakeholders to align with the program logic of the monitoring, evaluation, and reporting component of 'Protecting Victoria's Environment – Biodiversity 2037'.

Program evaluation is best done by an independent organisation free from any real or potential conflicts of interest arising from the evaluation.

Potential tests of the success of a citizen science program for biodiversity include (in order of increasing value):

People valuing nature

- The number of people engaged in citizen science and over what timeframe
- Whether the resources spent on citizen science result in improved biodiversity and social outcomes in key locations compared to alternative approaches (i.e., cost/benefit analysis)
- Improvements in knowledge, attitudes, skills, aspirations, behaviours of participants and their contacts toward biodiversity
- The number of additional resources (sustainable living, volunteer time, donation of funds) citizen scientists and those they influence committed to protecting biodiversity
- Proportion of participants joining environmental advocacy groups as a direct result of involvement in citizen science.

Biodiversity health

The specific changes in biodiversity health expected from citizen science knowledge need to be identified.

Potential measures include:

- volume of data gathered (e.g., number of observations/records, data sheets completed)
- quality of the data (e.g., proportion of erroneous data, measures of bias)
- degree to which citizen-derived data or papers arising influence decision-making or management planning
- degree to which the citizen-derived science influences on-ground outcomes, as defined by the objective and targets of the program and 'Protecting Victoria's Environment – Biodiversity 2037' (e.g., were better outcomes achieved for biodiversity in projects using this knowledge than in controls?).

Appendix 8 contains example evaluation frameworks.

4.20 Project examples

There is a wide variety of projects that could involve citizen science. Below are some examples:

- collecting data to improve our knowledge of the distribution of species, and the models derived from this information
- monitoring bushfire recovery of affected species, systems, landscapes within a fireground
- social surveys of the environmental beliefs and behaviours of people in Victoria
- experimental studies that aim to evaluate the performance of habitat improvement works
- collection of plant vital attribute data to inform models of ecosystem function in relation to disturbance
- long-term monitoring of sites to track changes in species abundance
- involving anglers and others in collecting data on fish populations, movement and catch locations
- engaging immigrant and non-English speaking communities in collecting data (e.g., bioacoustic, flowering phenology) as a way of connecting people with nature and understanding the nature of urban environments
- establishing remote cameras and preliminary screening of data (e.g., for pest animals at high biodiversity value sites with/without management).
- transcribing high value data from a range of sources, such as naturalists' notebooks, into information systems
- collecting data on the occupancy, effectiveness, and maintenance standard of already-installed nest boxes in their area (of which there are many across the state).

5 Conclusion

Citizen science involves volunteer citizens, in partnership with scientists, participating in scientific endeavours for community benefit. There are many citizen science projects currently underway in Victoria relating to biodiversity. They involve survey, monitoring, research, digital analysis, and communication, and occur in terrestrial, freshwater and marine environments.

A citizen science peak body, the Australian Citizen Science Association, formed in 2014 and a Victorian chapter formalised in 2018. Citizen science is being widely promoted and used throughout the world. A strong, co-operative citizen science network would benefit 'Protecting Victoria's Environment – Biodiversity 2037' by offering another constructive opportunity for people to be engaged in connecting with nature and addressing the challenge of protecting biodiversity.

Advances in technology have vastly increased the potential for data acquisition, storage, retrieval, sharing and analysis by citizens and therefore their capacity to collaborate on scientific projects.

Citizen science has the potential to contribute directly to the government's objectives (particularly Priorities 2–5 and 10) as detailed in 'Protecting Victoria's Environment – Biodiversity 2037'. A citizen science program could increase opportunities for all Victorians to connect with nature and enable them to act to protect biodiversity, increase the collection of targeted data for evidence-based decision-making, raise awareness of the importance of the natural environment, and leverage investment.

Collaborating with social (behavioural) scientists in program design is likely to increase the chance of successfully engaging people and influencing their behaviours, towards valuing and acting for nature – a key objective of the Plan.

As well as supporting delivery of 'Protecting Victoria's Environment – Biodiversity 2037', citizen science could be conceived as a service delivered to the community that equips community groups with the information, skills, and capabilities to answer the questions they find most important and interesting relating to their concerns for biodiversity.

The use of citizen science is not without risks, which include volunteer safety, data quality, and project uncertainty. Risks need to be identified and managed, and the costs of using a citizen science approach weighed against the biodiversity and social benefits.

An increasing body of evidence suggests that participation in the acquisition of knowledge via citizen science can increase community capacity, empower citizens and lead to increased participation in public policy and behaviours that benefit nature. By embracing and building the scientific capabilities in the Victorian community, citizen science could help initiate a new relationship between people and nature. In the 1970s, through initiatives such as *Land for Wildlife* and *Trust for Nature*, Victorian landholders were invited to voluntarily join with government in protecting biodiversity on their land. The opportunity now presents itself to invite all Victorians, and others with an interest, to voluntarily participate in the science of protecting Victoria's biodiversity.

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Appendix 1: Principles of citizen science

Citizen science is a flexible concept that can be adapted and applied within diverse situations and disciplines. The statements below were developed by the *'Sharing best practice and building capacity'* working group of the European Citizen Science Association, led by the Natural History Museum London with input from many members of the Association. These statements set out some of the key principles, which as a community, we believe underlie good practice in citizen science.

1. Citizen science projects actively involve citizens in scientific endeavour that generates new knowledge or understanding.
2. Citizens may act as contributors, collaborators, or as project leader and have a meaningful role in the project.
3. Citizen science projects have a genuine science outcome. For example, answering a research question or informing conservation actions, management decisions or environmental policy.
4. Both the professional scientists and the citizen scientists benefit from taking part.
5. Benefits may include the publication of research outputs, learning opportunities, personal enjoyment, social benefits, satisfaction through contributing to scientific evidence e.g., to address local, national and international issues, and through that, the potential to influence policy.
6. Citizen scientists may, if they wish, participate in multiple stages of the scientific process. This may include developing the research question, designing the method, gathering and analysing data, and communicating the results.
7. Citizen scientists receive feedback from the project. For example, how their data are being used and what the research, policy or societal outcomes are.
8. Citizen science is considered a research approach like any other, with limitations and biases that should be considered and controlled for.
9. However, unlike traditional research approaches, citizen science provides opportunity for greater public engagement and democratisation of science.
10. Citizen science project data and meta-data are made publicly available and where possible, results are published in an open access format.
11. Data sharing may occur during or after the project, unless there are security or privacy concerns that prevent this.
12. Citizen scientists are acknowledged in project results and publications.
13. Citizen science programmes are evaluated for their scientific output, data quality, participant experience and wider societal or policy impact.
14. The leaders of citizen science projects take into consideration legal and ethical issues surrounding copyright, intellectual property, data sharing agreements, confidentiality, attribution, and the environmental impact of any activities.

Source: European Citizen Science Association

Appendix 2: List of citizen science and biodiversity projects in Victoria

The following list includes a synthesis of citizen science projects at the time this paper was developed in 2020. The list is by no means exhaustive, and many projects have emerged since the time this list was created.

The Atlas of Living Australia and ACSA have developed Biocollect, a listing of citizen science projects in Australia. See http://biocollect.ala.org.au/. Wikipedia has a list of citizen science projects https://en.wikipedia.org/wiki/List_of_citizen_science_projects. The Australian Citizen Science Association also has a citizen science Project Finder webpage, see https://citizenscience.org.au/ala-project-finder/

Projects are listed in alphabetical order with the exception that VNPA projects have been grouped together.

Project title	Project type	Project objective	Contact details	Comments
Angler diary program	Freshwater	Catch trends, spawning success, survival, and growth rates for a range of fish species	http://agriculture.vic.gov.au/fisheries/science-in-fisheries/fisheries-research-findings/angler-diary-program	Since mid-1990s. Angler diarists are equipped with special diaries and rulers. They record how long they spend fishing, the number and size of fish they caught, and the gear used.
ANZSES (Australian and New Zealand Scientific Exploration Society)	Australian arid zone, Wet Tropics, Stewart Island	Remote, multi-disciplinary, 3 to 6-week scientific expeditions, collecting data in response to specific requests from agencies such as CSIRO, South Australian Museum, SA National Parks and Wildlife Services (NPWS), Qld NPWS	Fern.Hames@delwp.vic.gov.au	Expeditions comprised of several groups, each of which focussed on a particular field (e.g., mammals and reptiles/ birds/ archaeology…), was led by a professional scientist in that field, and included five other volunteer citizens. Expeditioners were trained in methodology for the first few days, and then integrally involved in field data collection for the remainder of the expedition. A non-profit organisation, which ran from mid '70s to mid '90s.
Australian Platypus Conservancy	Freshwater	Platypus biology	Australian Platypus Conservancy Box 22 Wiseleigh VIC 3885 Tel: (03) 5157 5568	Platypus sightings, platypus count, platypus group watch.

Project title	Project type	Project objective	Contact details	Comments
			Email: platypus.apc@westnet.com.au http://www.platypus.asn.au/	
Baywide monitoring Recreational Reefs	Marine	To monitor fish stocks during and after channel deepening To assess if artificial reefs attract fish	http://agriculture.vic.gov.au/fisheries/science-in-fisheries/fisheries-research-findings/angler-diary-program	
Beach Patrol	Marine	To help clean litter from the beaches of Melbourne		Collect data on litter types and sources.
Birdlife Australia Atlas and bird data	Terrestrial – birds	Bird distribution and abundance	http://www.birdlife.org.au/ atlas@birdlife.org.au	900,000 surveys 14 million records
Birdlife Australia Shorebirds 2020	Terrestrial – shorebirds	National shorebird population monitoring		
Birds in Backyards and Aussie Backyard Bird Count	Terrestrial – birds	What influences bird diversity in gardens etc. Increasing community understanding Diversity of birds	http://www.birdsinbackyards.net/	Started in 2008. 'Birds in Backyards' is a research, education and conservation program focussing on the birds that live where people live.
Clean Air Urban Landscape Hub	Terrestrial – frogs, mammals, insects	To monitor wildlife in Australian cities	https://nespurban.edu.au/platforms/caul-urban-wildlife-app/	People can record sightings of bell frogs, beneficial insects, and flying foxes. Users from all states and territories in Australia can participate.
ClimateWatch		Understanding seasonal changes	http://www.climatewatch.org.au/contact http://www.climatewatch.org.au/	Sponsored by the Australian Government and University of Melbourne.

Project title	Project type	Project objective	Contact details	Comments
		in wildlife behaviour		
Community Finding Fauna	Terrestrial – fauna	Response of wildlife to 2009 bushfires	http://delwp.vic.gov.au/__data/assets/pdf_file/0010/203959/VBRRA-P26-web.pdf	Project completed. Post 2009 bushfires. Community monitoring using remote cameras.
Dandenong Burrowing Crayfish	Freshwater	Distribution of burrowing crayfish and the potential impacts of stormwater outfalls	https://www.ari.vic.gov.au/ Arthur Rylah Institute, 123 Brown St, Heidelberg	See case study Appendix 4.
DigiVol	Data	Digitising the Australian Museum collections	http://australianmuseum.net.au/digivol	Worldwide volunteers.
Estuary Watch	Marine		http://www.estuarywatch.org.au/	Monitoring the condition of Victoria's estuaries.
EPA Victoria	Various		http://www.epa.vic.gov.au/our-work/programs/citizen-science-program contact@epa.vic.gov.au	Water and air monitoring in the Latrobe Valley. Established in 2014 as part of the Hazelwood recovery effort.
Feather Map	Terrestrial – waterbirds	To track the movement of waterbirds around Australia	http://feathermap.ansto.gov.au/	Citizens collect wetland bird feathers they find on the ground or in the water to help researchers create the first ever Feather Map of Australia. Collaboration between Australian Nuclear Science and Technology Organisation (ANSTO) and Centre for Ecosystem Science UNSW. Till 2018.
Field Naturalists Club of Victoria			admin@fncv.org.au	
Fishcare	Freshwater	To foster a concept of stewardship and personal responsibility by Victorian recreational fishers to fish	http://www.fishcare.org.au/	

Project title	Project type	Project objective	Contact details	Comments
		resources and the aquatic environment		
Fluker Post	Terrestrial – images	Protect natural environments	http://www.flukerpost.com/	Taking photographs from fixed photopoints.
Frog census	Freshwater – frogs	Frog census	frogs@melbournewater.com.au Melbourne Water http://www.melbournewater.com.au/getinvolved/protecttheenvironment/Pages/Frog-Census.aspx	Frog data added to VBA, ALA.
Frog ID	Terrestrial/aquatic	Frog monitoring	https://www.frogid.net.au/	Frog data used in research by Australian Museum.
FrogWatch:	Freshwater – frogs	Frog friendly habitat	http://frogs.org.au/frogwatch/index.html	
Fungimap	Terrestrial – fungi	Promoting study and conservation of macrofungi	Fungimap Inc c/o Royal Botanic Gardens Melbourne Private Bag 2000 South Yarra Victoria 3141 Telephone: (03) 9252 2374 Email: info@fungimap.org.au	Target species. Online field guide.
Gippsland Lakes Important Bird Area monitoring	Freshwater – birds		felkit@wideband.net.au	Local BirdLife East Gippsland Several years of bird counts across numerous sites using standard methods and a network of volunteers. Well-run in terms of standard methods, participant training, data collation and reporting.
Goongerah Environment Centre	Terrestrial – mammals	To protect East Gippsland forests from logging	http://www.geco.org.au/2/citizen_science	Citizens organising themselves to undertake monitoring for threatened species. Sample report in references.
Great Victorian Fish Count	Marine –fish	Record abundance of 25 key Victorian		In twelfth year. Involves 300–400 divers.

Project title	Project type	Project objective	Contact details	Comments
		marine fish species		
Great Victorian Koala Count	Terrestrial – mammal		http://www.delwp.vic.gov.au/	
Ground Parrots and fire	Terrestrial – bird		http://www.delwp.vic.gov.au/	Calibration of sound recordings.
I spy fish I spy frogs I spy catchment creatures	Freshwater – fish		Goulburn Broken Catchment Management Authority (CMA) Shepparton Office, (03) 5822 7700 or reception@gbcma.vic.gov.au https://www.gbcma.vic.gov.au/ispy_catchment_creatures/ispy_fish https://www.gbcma.vic.gov.au/ispy_catchment_creatures/ispy_frogs https://www.gbcma.vic.gov.au/ispy_catchment_creatures	Fish App contains descriptions of 21 native and 8 alien fish species found within the Goulburn Broken Catchment and allows users to record their catch at the push of a button. No feedback. Developed with Museum of Vic and Sumo software. Frog App – 20 frog species. Catchment creatures – not launched.
Koala counting and catching on Raymond Island (DELWP)	Terrestrial – mammal	Koala conservation	http://www.delwp.vic.gov.au/	Long-running project, involving up to dozens of people simultaneously to survey koalas (on particular days). There are different count and catch days with a somewhat different mix of participants (higher % of agency/vets etc. on catch days). People and relationships management has been a major component of this project.
LaTrobe University Wildlife Sanctuary citizen science program	Various	Various monitoring projects	www.latrobe.edu.au/wildlife Follow links	Frog census, stag watch, little creatures bio-blitz, fungi forays, waterbird surveys.
Major Mitchell's Cockatoo	Terrestrial – bird	To increase the size of the breeding population at Pine Plains, Victorian Mallee	http://www.delwp.vic.gov.au/	Monitor tree cavities to detect breeding by Major Mitchell's Cockatoo and competitors (annual spring). Excavate new cavities in trees to increase the number of tree cavities for breeding Major Mitchell's Cockatoo .

Project title	Project type	Project objective	Contact details	Comments
Melbourne BioBlitz	Various	Learning about the species in the city of Melbourne	nature@melbourne.vic.gov.au	26 events, 36 survey leaders, 17 organisations, 750 members of public, 913 sightings recorded.
Mulloway research	Freshwater – fish	Construct demographic data for Mulloway fishery	http://natureglenelg.org.au/wp-content/uploads/2015/03/Newsletter-No.-1 Final.pdf	
Moth Tracker	Terrestrial – insect	Tracking the Bogong Moth annual migration	https://www.swifft.net.au/mothtracker/	A place to record Bogong Moth sightings and help critically endangered Mountain Pygmy-possums.
Native Fish Recovery	Freshwater – fish	Engaging community in native fish recovery following 2009 bushfires	Fern.Hames@delwp.vic.gov.au	Project complete.
NatureShare	General		contact@natureshare.org.au http://natureshare.org.au/	For recording observations. Approximately 45 participants.
NatureWatch (see also VNPA)	Various	To understand more about the health of Victoria's natural environment, and how we can better look after it.	www.vnpa.org.au	Counting leaves on a threatened plant species, listening to frog calls, setting up motion-sensing cameras to monitor forest mammals, etc. NatureWatch brings together community groups, scientists, and land managers to develop and manage projects that get volunteers out into the field monitoring native plants and animals.
Owl monitoring in south Gippsland		Status of owls and associated species	Refer to the Victorian Bushfire Reconstruction and Recovery Authority (VBRRA) report.	Powerful owl monitoring in Gippsland.
PlatypusSPOT	Freshwater – mammal	Conservation and research of Platypus.	http://platypusspot.org/	Spot records, mobile app. Cesar, Melbourne Water, Wimmera CMA.
Port Phillip Baykeeper	Marine – various	To protect Port Phillip Bay	Baykeeper.ecocentre.com Phone: 0409 138 565 55A Blessington St St Kilda VIC 3182	Microplastic pollution: monitoring nurdles. Shoreline litter surveys. Monitoring flora and fauna.

Project title	Project type	Project objective	Contact details	Comments
			http://www.bay-keeper.com/ https://www.trybooking.com/Booking/BookingEventSummary.aspx?eid=201356	
RedMap	Marine		vic@redmap.org.au http://www.redmap.org.au/	Redmap (Range Extension Database and Mapping project) invites the Australian community to spot, log and map marine species that are uncommon in Australia, or along particular parts of our coast. Led in Vic by Museum Victoria.
Reef Life Survey:	Marine	To conserve marine life	enquiries@reeflifesurvey.com http://reeflifesurvey.com/2020-2/	Marine sightings. Map of where surveys have been undertaken.
School of Ants	Terrestrial _ invertebrate	International ant research	http://www.schoolofants.net.au/	Analysing data and not taking new data.
Sea Search	Marine		seasearch@parks.vic.gov.au	Parks Victoria. Community-based monitoring program for the marine national parks and sanctuaries.
Sherbrooke Lyrebird Study Group	Terrestrial – bird	The elucidation of the life history and ecology of the Lyrebird, with reference to Sherbrooke Forest Park, Victoria.	bincoll@melbpc.org.au	50-year study of lyrebirds. 12 members.
Snapper tracking – Port Phillip Bay	Marine – fish		http://agriculture.vic.gov.au/fisheries/science-in-fisheries/fisheries-research-findings/tracking-snapper-in-port-phillip-bay	For tagged snapper, citizens are asked to: • record the tag number • record the location of capture (ideally GPS coordinates) • record the time and date • call the phone number on a tag as soon as possible.
Stuffed Murray Cod in pubs	Freshwater – fish		https://paulhumphriesriverecology.wordpress.com/2015/02/03/stuffed-murray-cod-in-pubs /	PhD project. Citizens advise of locations of pubs with taxidermied fish.

Project title	Project type	Project objective	Contact details	Comments
Upper Barwon Landcare Network	Various	Biodiversity conservation	http://www.ubln.org.au/biodiversity-survey/	Species observations in Upper Barwon Landcare Network region.
Victorian Peregrine Project	Terrestrial – bird	Monitor nest occupancy and breeding performance of Peregrine Falcons (PF) across Victoria. Support PF nest sites in industrial and urban environments	http://www.delwp.vic.gov.au/	Monitoring adults at active nest sites for leg bands. Banding nestlings each spring. Liaise with industry on the management of sites where PFs are trying to breed. Install nest boxes where appropriate. Remove inactive nest sites. All volunteers. Project Leader, VG Hurley. Four key active members (climbers/banders). Fifty associated volunteers (interested in single sites or provide rehab of injured birds). Project is registered with BirdLife Australia. Funding through contracts with industry for nest site management etc. where appropriate. Provide policy advice and advocacy for raptors more generally.
VNPA – Great Victorian Fish Count	Marine	Record abundance of 25 key Victorian fish species	https://vnpa.org.au/programs/reefwatch/	In twelfth year. Involves 300–400 divers.
VNPA – Adopt a Sponge	Marine	Monitor sponge recruitment at Blairgowrie Pier	https://vnpa.org.au/programs/reefwatch/	'Operation Sponge' at Blairgowrie Pier has become the site of what is thought to be the largest marine sponge transplant ever attempted, in the world. This offers divers the chance to 'adopt a sponge' and help monitor the growth of transplanted sponges.
VNPA – Settlement Plate Surveys	Marine	Monitor shellfish recruitment	https://vnpa.org.au/programs/reefwatch/	Using settlement plates to detect oyster and mussel recruitment.
VNPA – Underwater camera at Pope's Eye	Marine	Video monitoring at Pope's Eye	https://vnpa.org.au/programs/reefwatch/	Collating a species list at Pope's Eye using exciting new underwater video technology. Compiling a highlights reel of footage with interesting species.
VNPA – Grass Tree Monitoring	Terrestrial – plant	Monitor health of Grass Trees in response to Phytophthora cinnamomi		Started in Brisbane Range National Park's (NPs) in 2007, now also in Wilsons Promontory NP and Otway region.
VNPA – Grasslands	Terrestrial	Monitoring threatened species such as Golden Sun Moth,	https://vnpa.org.au/programs/naturewatch/	Small-scale projects. Many run in partnership with Merri Creek Management Committee.

Project title	Project type	Project objective	Contact details	Comments
Threatened Species		Growling Grass Frog Plains Yam Daisies		
VNPA – Caught on Camera	Terrestrial	Using motion-sensing cameras to monitor mammals and other ground-dwelling species	https://vnpa.org.au/programs/nature watch/	Started in 2012. Support from ARI and then Eco Insights. In Wombat State Forest and Bunyip State Park, looking at the impact of fire on mammals, and in Hindmarsh comparing mammals on revegetation sites, cleared sites and remnant sites. Also supporting a smaller scale project in Mt Worth State Park and starting a new project in Macedon Regional Park.
VNPA – Communities Listening for Nature	Terrestrial	Using sounds recorders and automated sound recognition technology to monitor birds in Victoria	https://vnpa.org.au/programs/nature watch/	Started in 2016. Set up in Bunyip State Park and Mt Worth State Park. More locations in 2017.
Victorian Wader Study Group	Marine – waders	To conduct a long-term comprehensive study of waders and terns throughout Victoria	http://www.vwsg.org.au/about.html	Not-for-profit organisation of around 140 volunteers.
Weed biological control (national – DELWP is partner):	Terrestrial – plant	Weed control	https://biocollect.ala.org.au/#isCitizenScience%3Dtrue%26max%3D20%26sort%3DdateCreatedSort%26isWorldWide%3Dfalse	National site for recording the distribution of weed biological control agents, with 115 users, and 2,500 records.
Wildlife Spotter	Data	Identifying animals in remote camera images	https://wildlifespotter.net.au/	Over 51,000 participants. In partnership with the ABC for national science week. Funded under the 'Inspiring Australia' program. Vic.
Woodland Birds for Biodiversity	Terrestrial – bird	To enhance the conservation of threatened and declining woodland birds in the temperate	http://birdlife.org.au/projects/woodland-birds-for-biodiversity	Effectiveness of habitat rehabilitation. Population monitoring at priority sites.

Project title	Project type	Project objective	Contact details	Comments
		regions of south-eastern Australia		
Seal the Loop			info@ecocentre.com	Bins for collection and analysis of discarded fishing tackle.

Appendix 3: Case studies

To understand the details and complexities associated with implementing a citizen science program, a number of case studies were developed. Interviews were conducted in late 2016.

Case study questions – citizen science

The following questions were used in interviews to guide the development of case studies.

1. What citizen science projects do you run?
2. When did they start/expect to finish?
3. What spatial scale?
4. Type of information being collected?
   Is there someone you would describe as a project 'champion'? Where did they come from and what is their particular role?
   How is the project funded?
5. How many people are involved? Staff/volunteers. Volunteer backgrounds?
6. Is there a coordinator? If so, what are the key attributes of a good coordinator? (or other governance approach?)
   What were the steps in setting up your citizen science program?
7. What were the general timelines for promotion, signing people up etc.?
8. How did you:
   a. recognise right fit/select projects as a good fit for citizen science?
   b. reach, identify and screen potential participants?
   c. match skills to projects?
   d. train, equip and communicate with volunteers?
   e. facilitate data entry and validation? Does your project use digital tech/apps? (which)
   f. store data?
   g. provide feedback?
   h. celebrate the project?
   i. evaluate the project?
9. Were the data used? What for? How useful were they?
10. Did participant's behaviour change as a result of involvement? How? (E.g., more active in conservation, joined an advocacy group).
11. How would you improve the project if you did it again?/What are your top tips for establishing a successful citizen science project? Is there additional support that would allow citizen science to get more out of participants?
12. What are the main risks/issues/problems?
13. How could citizen science be expanded in Victoria/what do you think are the key barriers?
14. How much untapped potential do you think exists for recruiting volunteer citizen scientists? Where does it lie?
15. Are there any other citizen science projects you are aware of?
16. Are you a member of ACSA or another relevant network/group?

Citizen science case study – Victorian National Parks Association

Background

VNPA initiated its citizen science program in 2007 and a proprietary framework for the program was developed. There are two umbrella programs – NatureWatch and ReefWatch (see below). Typically, a NatureWatch project is established with an expected longevity of around 10 years. Preliminary planning is followed by a one–two-year pilot that is evaluated before committing to the longer term. Design involves professional scientists and land managers collaborating with a community of citizen volunteers, usually (but not always) an established group. Their involvement in proposing relevant local projects and in design is very important in maintaining their 'buy in'. Projects can be cross-tenure and private landholders may also be involved where their land is affected. Biometric advice is at the discretion of the scientists involved. Projects aim to achieve both engagement and collection of valuable data objectives. VNPA projects all have on-ground management applicability.

Project management

Part-time coordinators manage each of VNPA's programs. The coordinators support projects through ensuring enough people are engaged, managing equipment, training, permits, etc. Project coordinators need to have a wide range of skills including in project management, communication (writing, understanding and working with diverse volunteers), and managing equipment. A science background is preferable. A project 'champion' to work with the project coordinator and organise locally is very important to project success. Funding is sourced from numerous sources including the VNPA budget, philanthropic organisations (e.g., Helen Macpherson Smith Trust), grants (e.g., Threatened Species Community Grants), National Parks and Wildlife (NPW) Foundation and corporate sponsors. VNPA has developed its own citizen science model (VNPA IP) that is applied to project development. Volunteers are recruited via existing local groups (which are the most reliable), a database of 650 registered volunteers (who receive a monthly email newsletter), university clubs and local media advertising. Volunteers 'self-filter' against skills required to undertake tasks, and project-specific training is provided. Data are processed manually by volunteers who must commit their time to 1 day/week or fortnight, and are stored in-house on a server.

Project communication, evaluation, and outcomes

Face-to-face meetings with local community volunteers occur at least once per year, usually more often – sometimes as regularly as once every three weeks throughout intensive field work periods. These meetings may combine report back, training and celebration – often these combined meetings are larger events attended by the wider community. Project reports are published on the VNPA website. Reporting to VNPA members is via social media including Park Watch magazine.

Evaluation of projects is embedded in staff review processes, reports to VNPA council, as well as in project-specific measures. Evaluation of behaviour change in participants is difficult to achieve. A survey of participants, including volunteers, scientists and land managers has been undertaken, which included narratives about learning and self-assessed behaviour change.

Information derived from projects has been used for operational outcomes, for example by Parks Victoria to target feral species management and leverage internal funding for threatened species protection.

Potential pitfalls

Volunteers benefit from clear, ongoing communication including feedback. Failure to do this effectively undermines project success.

For volunteers to remain engaged they must be effectively involved (empowered) at the outset, including in project proposal and design phases.

Growing the sector

VNPA and EPA have facilitated a network of citizen science practitioners, and a group has now become the Victorian Chapter of the Australian Citizen Science Association.

In recent years, there has been a lot of excitement about the potential of citizen science. Realistically, there are numerous limits to growth, including developing solid frameworks to support volunteers and maintaining interest. Mass participation is an unlikely short-term outcome.

VNPA is a member of the ACSA. Consultancy services that offer advice on establishing citizen science programs or are engaged to establish local projects are potentially available.

Important issues for the scoping paper

- Support for networking/developing a community of practice among citizen science providers
- Developing a program that achieves volunteer buy in and sustained commitment
- Capacity to report to volunteers in a timely way
- The importance of investing in coordination and selecting a person with a high level of enthusiasm and range of skills
- Realistic expectations about the potential of citizen science to contribute to the goals of ‘Protecting Victoria’s Environment – Biodiversity 2037’.

Victorian National Parks Association citizen science projects, 2016–2017

NatureWatch

- **Caught on Camera** – is an umbrella program for projects that involves analysing remote camera wildlife images and habitat data. Examples include recovery of small mammals after the 2009 fires, and recovery of ground-dwelling mammals post revegetation in the Wimmera.
- **Communities Listening for Nature** – is a new project collaboration with Museum Victoria. It aims to collect audio files of Victorian bird calls for an audio library to be curated by the Museum. The collection will be publicly accessible. VNPA engages established groups, including consideration of how people will interact with the data (e.g., desktop or online via the cloud). The museum provides support from its scientists.
- **Grass tree monitoring** – permanent 8 m quadrats in several locations. Morphometric, ecosystem health and soil data are collected approximately twice/year. Samples are tested for *Phytophthora cinnamomi* following protocols. The project aims to look at change over time.
- **Grasslands Threatened Species monitoring** – has involved a number of small-scale projects. Currently the focus is on support from the Merri Creek Management Committee in monitoring the outcomes of their activities and annual Golden Sun Moth surveys. Plains Yam Daisy, Striped Legless Lizard and Matted Flax lily have previously been a focus. The Growling Grass Frog is currently being surveyed annually in the City of Whittlesea.

ReefWatch

- **Great Victorian Fish Count** – involves dive club members monitoring a select list of fish species along Victoria's coastline.
- **Adopt a Sponge** – monitoring sponge recruitment at Blairgowrie Pier. 'Operation Sponge' at Blairgowrie Pier has become the site of what is thought to be the largest marine sponge transplant ever attempted, in the world. This offers divers the chance to 'adopt a sponge' and help monitor the growth of transplanted sponges.
- **Settlement Plate Surveys** (project title not yet confirmed) – monitoring shellfish recruitment at sites in Port Phillip Bay. Using settlement plates to detect oyster and mussel recruitment.
- **Underwater camera at Pope's Eye** (project title not yet confirmed) – video monitoring at Pope's Eye. Collating a species list at Pope's Eye using exciting new underwater video technology. Compiling a highlights reel of footage with interesting species.

Citizen science case study – Dandenong Burrowing Crayfish

Background

Yarra Ranges Council contracted the Arthur Rylah Institute to participate in surveys of burrowing crayfish to inform its stormwater management plan. A citizen science approach was adopted due to the presence of many local community groups. Funding was via the Threatened Species Protection Initiative (TSPI): Critical Action and Strategic Partnerships Grants and Melbourne Water. The project aimed to improve understanding of the distribution of burrowing crayfish and the potential impacts of stormwater outfalls on these and other threatened species.

Project management

Volunteers were recruited from existing environmental groups ('Friends' groups), universities and local individuals via the council website and the local paper. There were more volunteers than the capacity of the project to accommodate them. Volunteers met at a specific location each day of sampling and were provided with background to the project by Yarra Ranges Council. An ARI scientist provided input on survey sites, background ecological information on burrowing crayfish and training of volunteers in how to use crayfish traps, which volunteers then set and collected. The scientist provided species identification, which is difficult on this group of crayfish. Small gifts, including posters and bags, were given to volunteers as rewards.

Project communication, evaluation, and outcomes

Excellent communication was seen as a critical element for the success of this project. Background information on what was being done and why, was disseminated to all participants. All participants reported that they increased their knowledge. Crayfish records were retained by Council and incorporated into the stormwater management plan. Records will be used to identify priority stormwater drains for modification; a major benefit of the project given the significant expense modification. DELWP staff, council engineers and the friends group attended a follow-up council meeting.

As a result of the success of this project, further citizen science work is being discussed.

Important issues for the scoping paper

- Using established networks
- The value of partnerships
- The importance of communication
- Science input to design, analysis, communication and training, and reporting.

Citizen science case study – Fungimap

Background

Fungimap is a national program aimed at improving knowledge of Australian fungi. It was initiated in 1995 and incorporated in 2005.

Tom May of Royal Botanic Gardens Victoria (RBGV) is currently chair of the management committee, which includes members from across Australia. RBGV hosts the Fungimap office and provides information technology and human resources support. Staff are employed by the RBGV on behalf of Fungimap, but Fungimap finances are independent of RBGV. This close association is consistent with the community engagement aims of RBGV and benefits mycologists at the RBGV.

The project obtains funding from memberships, a bookshop, book royalties, donations, state government grants, philanthropic trusts, CMAs/NRM bodies, and commonwealth agencies and programs such as the Atlas of Living Australia (for set up of data transfer mechanisms).

The main activity is a mapping scheme where spot records of fungi including location, time, habitat, and substrate data are collected. Other projects are undertaken depending on funding. TSPI funding has allowed rare fungal species to be targeted. In this instance, abundance of fruiting bodies and zero records are also recorded.

Data are stored on a server at the RBGV and made publicly available through the Atlas of Living Australia.

A key step in the development of Fungimap was incorporation, which allowed Fungimap to apply for grants, cover insurance etc. A management committee was also formalised.

Project management

A coordinator (0.4 Full Time Equivalent) and project officer (1 day/week) staff Fungimap (up to 2 FTE have been involved when funding permitted). A team of approximately 10 volunteers attend the office 1 day/week. Some have committed their time for 10–15 years.

Attributes of a good coordinator include the ability to multi-task, work under pressure, network/liaise with volunteer organisations. Knowledge of fungi is NOT a prerequisite.

Grants (e.g., TSPI) have allowed progressive development of tools, such as data collection sheets, of long-term benefit.

Data entry for the recording scheme is via transcription of emails or via a spreadsheet, but would preferably be via an app or the web. Government could play a helpful role here in facilitating the availability of new technologies. Project data are stored on a server at the RBGV.

Project communication, evaluation, and outcomes

A passive approach is applied to recruiting via the website and Facebook. Field naturalists and fungal study groups provide a major source of participants. Recently, people with an interest in photography have been recruited. An eNews bulletin is published.

Photographs are used to verify species identification, along with investigation of outliers. Recorders who make regular errors are subject to higher levels of verification and asked for proof in terms of photo evidence. Any doubtful records are flagged in the database.

Fungimap would like to do more online and workshop training in identification and recording skills for recorders, and increase the pool of expert checkers of incoming data (particularly via online tools available outside of the main office).

Most participants are located in cities. Extra attention is given to volunteers in strategic (often rural/remote) locations.

Participants tend to have a pre-existing interest in nature conservation. There is potential to increase involvement via associated interest groups such as photographers.

Fungimap data has made fungi tractable in conservation, significantly increasing our knowledge of fungi (over 100,000 records). This has enabled us to understand the conservation status of species. Data has been used in bioclimatic modelling, supporting nominations under the Flora and fauna (FFG) Act and in achieving an IUCN listing. Fungimap data has informed Commonwealth State of the Environment reporting.

Potential pitfalls

Taking the time to get governance and financial administration securely in place, doing less but more thoroughly, and developing long-term partnerships are things that could be done to improve future projects.

Fewer, larger projects can be more rewarding. Small projects come with a high administrative cost.

Growing the sector

Funding is needed for capacity development of relatively small providers of citizen science.

Government could play a role in brokering networks across the sector, providing a source of expert advice on citizen science, making technologies available to smaller organisations, facilitating events at which volunteers could be recruited (e.g., new migrants), and advising on best use of funding.

There may be untapped potential in recruiting more volunteers, such as photographers.

Important issues for the scoping paper

- How to align the strategic goals of volunteers/partners with government 'Protecting Victoria's Environment – Biodiversity 2037' goals
- Government's role in supporting the sector, facilitating partnerships
- The relative benefit of a few, large projects versus many small ones
- Allocating a funding pool to support infrastructure development and/or access, and sector development.

Citizen science case study – Ground Parrot

Background

The project involved studying the relationship between the Ground Parrot and fire in heathlands of east Gippsland.

Project management

The project was part of a major initiative called HawkEye looking at long-term monitoring of the impacts of fire on biodiversity. A detailed project plan and study design were prepared by a DELWP scientist.

Volunteers were involved in the field work component. One couple undertook repeat surveys at a site at night on a weekly/fortnightly basis. Also, approximately eight Friends of Mallacoota helped to calibrate human observers and sound recorders by collecting distance and bearing information of Ground Parrot calls.

Data collected by volunteers were used as part of the project analysis, which resulted in a published paper.

There is untapped potential to involve more volunteers in Gippsland.

Issues and lessons

Issues included safety of people when out at night and because of weather conditions, including lightning. Safety briefings, communication, and limits on distance to a vehicle etc. were important considerations.

The cost/benefit of involving volunteers was an issue. Training people who are prepared to make a long-term commitment has more benefit. Projects require delivery on time and within budget, and this is a tension with the use of volunteers who may need more flexibility. Involving volunteers changes the emphasis within a project toward servicing their needs and may require a different skill set.

Citizen science case study – Office of Environment and Heritage NSW

Background

Erin Roger oversees citizen science for OEH and is Chair of the ACSA. She has been in the permanent role for three years. Erin provides advice and guidance to all Divisions within OEH and brokers partnerships with others, such as the Australian Museum, which provides a platform for image storage and analysis.

Drivers

A three-year strategy and policy statement guide citizen science within OEH https://www.environment.nsw.gov.au/research-and-publications/your-research/citizen-science

A knowledge strategy identifies key knowledge requirements.

Funding of the program is provided by OEH. Funds are also sourced from programs such as Saving Our Species.

Social research is included. A recent project investigated the motivations of 500 people toward volunteering and citizen science. There was a poor understanding of the term citizen science. Respondents commented that they hadn't done well at school in science and so thought they lacked the skills required to participate. OEH learnt that projects should not be branded as citizen science (c.f. Wildlife Spotter) and that the role volunteers are being asked to play should be made very clear at the outset.

Biodiversity and social objectives drive projects. For example, public concern about the Bellinger River Turtle following death of the adult turtle population has led to developing a community-driven project to monitor turtle population recovery.

Program management

The program coordinator requires scientific expertise combined with excellent networking capabilities and an ability to form partnerships.

A toolkit has been prepared to assist staff with project development and delivery.

A separate unit in OEH handles volunteer paperwork, waivers etc.

Data are managed at the project level with relevant data contributed to the wildlife atlas. Project managers are responsible for curating data. Data sharing agreements are handled by another unit in OEH.

Project communication, evaluation, and outcomes

Yammer is used as an internal OEH communication tool e.g., to circulate recent articles on the value of citizen science, the validity of citizen science data, and the value of incidental observations.

Statistics gathered in association with Wildlife Spotter indicated most volunteers were recruited via Facebook and radio. Demographic data showed that a wide range of age groups were represented.

Working with organisations with a large member base (e.g., Australian Museum, Birdlife Australia) is helpful. Early placement of advertisements in their magazines provides the necessary lead-in time.

OEH would like to have in place systems to match skills to roles. The ALA is exploring developing an expertise engine, but one is not yet in place.

Discount vouchers and certificates are used as rewards. Volunteers with >50 hours get a free National Parks Pass.

Evaluation of the first year of the citizen science strategy is coming up (refer to Cornell Uni evaluation http://www.birds.cornell.edu/citscitoolkit/evaluation/instruments).

Potential pitfalls

There has been some scepticism from the science community, which has been countered by circulating peer reviewed literature on the value of data derived from citizen scientists.

The challenges of liaising widely across the agency are a constant demand and many groups need to be consulted. External groups have more flexibility and can respond more rapidly.

Citizen science is a rapidly moving space. Flexibility and controlled risk taking are necessary to meet stakeholder expectations.

Survey data shows that people trust government with data and information.

Growing the sector

The sector would be assisted by distributing best practice framework and knowledge and a toolkit to share information.

ABS data indicates that volunteering is decreasing. There is potential for citizen science to extend what it means to volunteer. Volunteering might mean working on a project online from home for 10 minutes, etc. We need to provide opportunities that match the way people live their life.

Important issues for the scoping paper

- Managing the tension between government accountability and approval processes and the need to provide timely feedback to participants
- Clear authorising environment (policy) and strategy
- Need to develop a community of practice with citizen science providers (e.g., via ACSA).

Citizen science case study – EPA

Background

The Environment Protection Authority Victoria (EPA) has a number of citizen science projects relating to water and air quality monitoring, and pollution, including monitoring microplastics, odours and noise.

Citizen science sits in the science division within the EPA.

Following the 2014 Hazelwood fire in the Latrobe Valley, water and air quality monitoring was undertaken by citizens. These projects were co-designed with community members and included developing a revised air quality monitoring network, with a co-design panel consisting of 25 members of the community (half selected at random and half from established groups) meeting over three sessions. The budget was specified. This gave the community a strong voice and high level of engagement.

Microplastics are monitored in Port Phillip Bay and its catchment. Sustainability Victoria is involved as a partner agency.

Project management

The project has a full-time citizen science coordinator. Citizen science was recognised as offering an innovative approach to collecting environmental data and engaging with community.

A strategy and framework document have been prepared as well as a toolkit for regional staff. A UK decision tree for assessing whether citizen science is a suitable approach has been useful (Pocock et al. 2014; see Appendix 6).

Steps in setting up the program included looking at other organisations' citizen science programs in Australia and internationally (including EPAs in other countries) and understanding how EPA Victoria wanted to use citizen science – for engagement or proactive collection of data.

While early work emphasised engagement, inevitably the question about the value of the data and point of collecting it arises. It is important to engage with scientists from the outset to frame the question and study design to ensure projects have meaningful outcomes. In addition, the EPA has created a framework that promotes active community participation through co-design, co-monitoring, and co-interpretation to achieve a shared understanding of the science.

Aggregation of the top ten pollution events reported by the public is being used as a basis for assessing future knowledge requirements and scanned for potential future citizen science projects.

The program is aiming to increase the number of EPA regional staff that are engaged in identifying potential citizen science projects.

Partnerships with several universities are allowing exploration into the use of small sensors for monitoring.

Data collection is via field data sheets and online forms (using ALAs Biocollect custom forms). An app and capacity to map data would be beneficial.

Project communication, evaluation, and outcomes

In the Latrobe Valley, training in water quality monitoring was provided and, on completion, volunteers were 'signed off' as proficient. One-on-one interviews were not required. Volunteers were aware that they could be removed from the list of monitors.

Ten water quality kits were made available in the Latrobe project. Originally, a library loan system was envisaged. This wasn't practical (e.g., when the EPA office was closed) and the system has morphed into one where the kits remain with community members who pass them on to each other.

In the future, celebration of milestones is envisaged involving event days, sharing people's stories on the web, etc.

Evaluation is undertaken at the project level. The EPA employs two social scientists (both directly and through BehaviourWorks). Social data collected includes attitudes to environment, how to improve volunteer engagement, whether participants felt included, whether training was adequate, and what was learnt.

Potential pitfalls

An inadequate level of investment is a risk. If you are going to do citizen science, then do it well.

Developing the data storage systems, and capacity to upload data simply, early in the project are both critical.

Start with a key research question that has meaningful application to policy/decision-making/management. Engage with policy staff to determine their needs and willingness to accept community-derived data. BioBlitz-style citizen science is very narrow in scope. There is potential to investigate deeper questions.

Seek commitment from the organisation (e.g., the OEH policy statement).

Be transparent regarding the objective for collecting data and set realistic expectations for participants.

Growing the sector

There is a need to map out who is doing what across the sector and to look at options for collaboration. The ACSA Victorian chapter is an important move towards facilitating collaboration within the sector.

There remains untapped potential for recruiting volunteers, particularly via established groups. There are many groups with lots of energy and enthusiasm to get involved in worthwhile projects (e.g. field naturalists, friends groups etc.).

EPA is a member of the ACSA.

Important issues for the scoping paper

- Willingness of the organisation to engage at a high level with citizens in projects they co-design
- Attitude of policymakers to citizen science data and their use in decision-making
- Need to develop project plans to a detailed level, including precise budgeting for data capture, storage, retrieval, and analysis
- Transparency regarding project objectives, what citizens can expect, and the capacity of data/science to influence policy outcomes.

Citizen science case study – Field Naturalists Club of Victoria

Background

The Field Naturalists Club of Victoria (FNCV) has been involved in citizen science activities since its establishment in the 1880s. The FNCV is one of numerous field naturalists clubs in the state. Others include Ballarat, Bendigo, Ringwood, and Mornington. The South East Australian Naturalists Association http://environmentvictoria.org.au/group-member/south-east-australian-naturalist-association/ acts as an umbrella group for field naturalists clubs in south-eastern Australia.

Project management

Currently, FNCV are involved in a number of projects with Parks Victoria including 'Climate Trails' and Eastern Fauna Focus (fauna surveys at parks along the east side of Melbourne including Cardinia, and Jells Park). Remote cameras (3 weeks), harp traps, frog surveys, tile grids (which are popular) are deployed at 100 sites. At the last session, four groups of 20 people participated, 25% of whom had not participated previously. Most are recruited via the FNCV Facebook page which has 3,500 'friends'. Participants include retirees, interested employed individuals, professional biologists (although this is currently just two people with others progressing via tertiary studies), and students. Some students are motivated by the potential for career enhancement through learning wildlife trapping and handling techniques.

Piloting processes, as is being done with Eastern Fauna Focus, allows for refinement of methods. This project includes data analysis by participants with the aim of publishing results in the Victorian Naturalist.

Previously, the FNCV worked with ARI on post 2009 fire recovery http://www.delwp.vic.gov.au/__data/assets/pdf_file/0010/203959/VBRRA-P26-web.pdf. Remote cameras were used at 20 sites in the Black Range, Beechworth, Eildon etc. Volunteers were involved in the field and also in checking remote camera images.

Manningham City Council requested citizen science be incorporated into a fauna survey project they funded. Around eight volunteers reviewed thousands of images via Dropbox, isolating those with animals to be identified by more experienced project staff.

ResourceSmart schools http://www.resourcesmartschools.vic.gov.au/ provides a sustainability framework to interact with primary school teachers and students.

Many observations remain in field notebooks. Technology that allows simple input of data is preferred. The VBA is not the only source of useful records. For example, eBird was able to add 40% more records to compiling an historical fauna list for Currawong Bush Park.

Project communication, evaluation, and outcomes

It is important to capture people's imagination and think about what excites them – e.g., making new discoveries. Good projects involve iconic organisms but are unobtrusive into the life of the organism (e.g., Hooded Plover monitoring).

The Royal Australian Ornithologists Union (now BirdLife Australia) Atlas project is one of the biggest and longest running citizen science projects. Participants in the Atlas project responded to the challenge of adding data from areas where none had been recorded previously.

People post images of species to Facebook seeking identification. They can be unaware that field guides can assist them to make their own identifications. Moderators are needed to check records for validity and respond to requests for information.

Deakin University has a Facebook page seeking volunteers to help postgraduate students with their projects.

Potential pitfalls

Without ongoing supervision, there is a risk that people who attend sessions will adopt and apply techniques improperly and without obtaining the necessary permits e.g., people obtaining their own remote cameras that, if used with a bait station, would require a permit.

Important issues for the scoping paper

- Recognising that people input data and source information using numerous systems and will use the platforms that suit them best and deliver the outputs they need
- The value of piloting projects to test that they are viable and deliver the desired outcomes
- The dispersed nature of groups with an interest in natural history

- The role of moderators in vetting data and spreading the burden of assisting less experienced participants.

Appendix 4: Coordinator attributes

The following attributes were obtained from case study discussions and are provided to inform key selection criteria for a citizen science coordinator:

Coordinators require:

- project and budget management skills
- excellent communication skills (e.g., writing, presenting, web publishing) and knowledge of social media
- people skills (cultural safety capability, high level of skills in working in partnership with Traditional Owners, and working with diverse communities)
- ability to broker partnerships
- a science background preferably.

Also, depending on the program, they may require:

- experience in managing equipment (e.g., remote cameras).

Example: NSW Office of Environment and Heritage Key Selection Criteria

As per advertisement, supplied in 2016, for a Scientist (citizen science) EO7

- Assist in delivering citizen science projects that support the Saving Our Species program and are consistent with government strategies and priorities
- Ensure the application of scientific rigour across the organisation regarding citizen science, including external parties and out-sourced activities
- Manage aspects of citizen science project implementation, including monitoring project plans, coordinating resources, and managing budgets to ensure that citizen science projects are delivered to agreed timelines and quality
- Develop and maintain a range of collaborative networks across OEH/EPA, universities, government agencies and other research providers to support the delivery of citizen science projects that support the Saving Our Species program
- Prepare and deliver presentations on citizen science as required, to internal and external groups using clear language, to facilitate effective implementation and promotion of citizen science
- Contribute to communication within and between programs areas and ensure that communication channels are appropriate, efficient, and effective for the target audience.

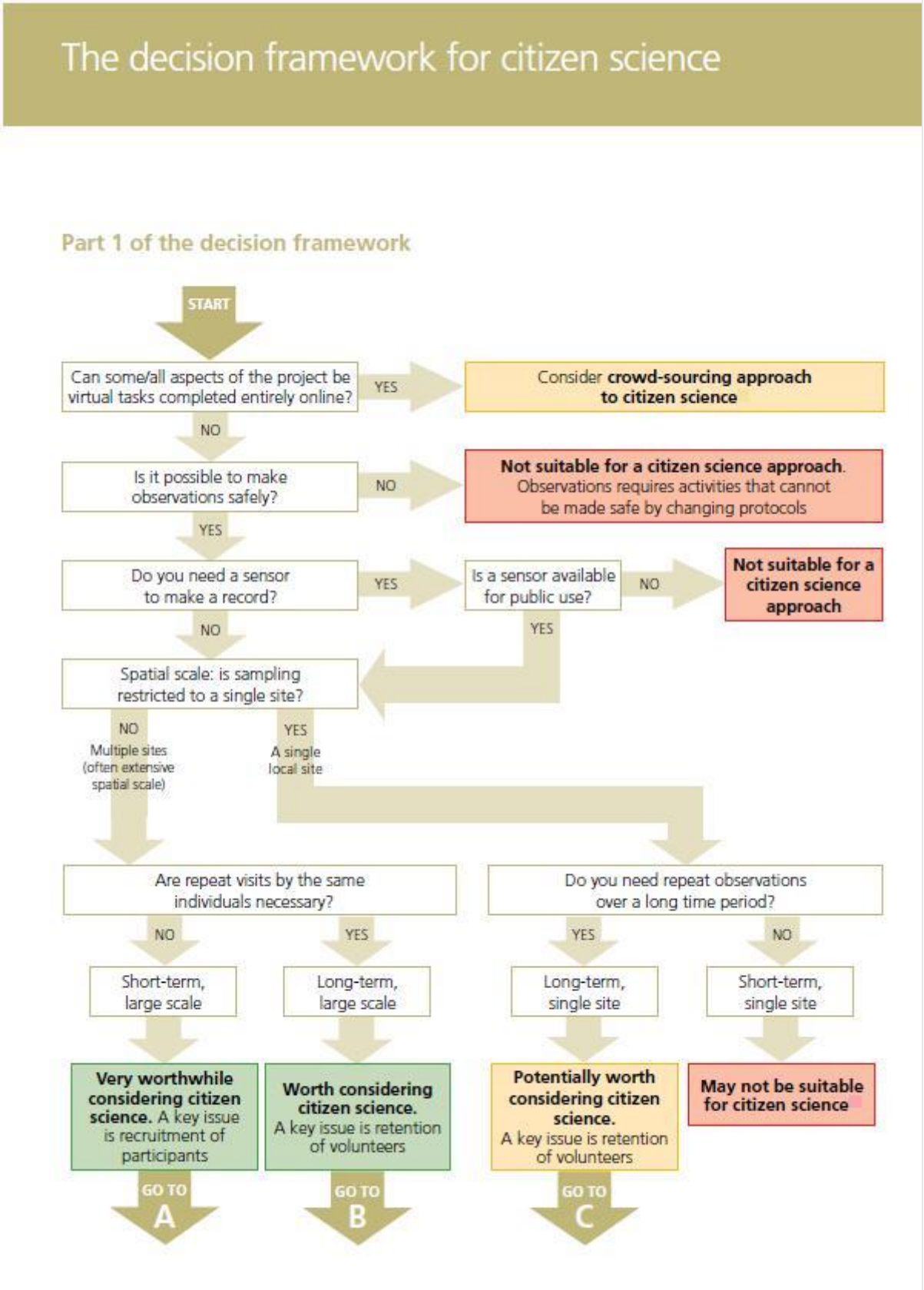
Appendix 5: Data collection and display platforms

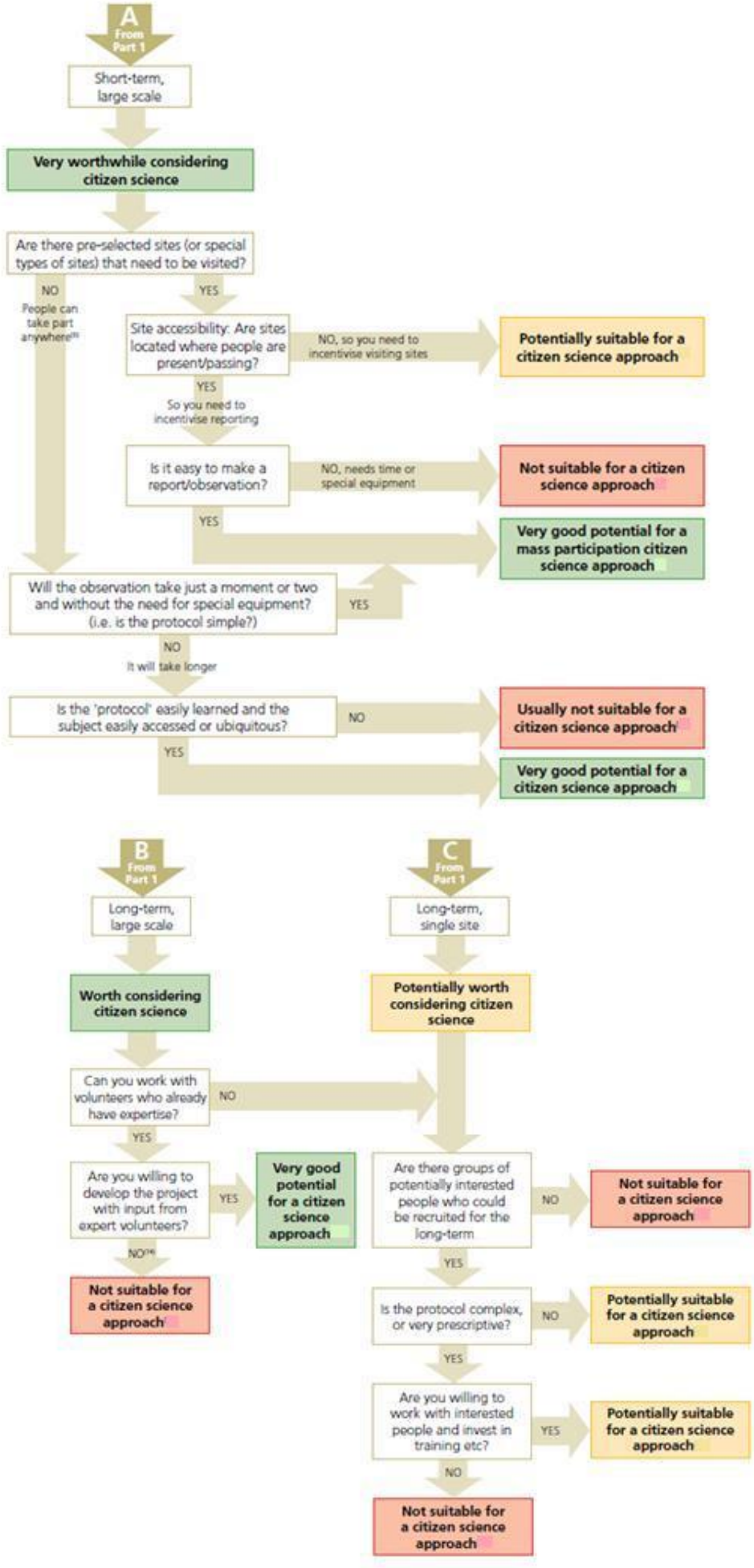
Name	Description	Online Portal	Smart Phone App-iPhone	Smart Phone App-Android	Photo upload	Map display	Geoprivacy settings	Data export	Level of customisation	Ease of implementation	Cost
Atlas of Living Australian Field Data Software	Open Source software that can provide data collection and management capabilities Requires knowledge of deploying Java applications to web servers.	✓	✗	✗	✓	✓	✓	✓	High	Low	Free
ArcGIS Collector	ArcGIS plug-in that allows data to be collected from the field via smartphones.Requires an ArcGIS license.	?	✓	✓	?	✓	?	✓	?	?	?
BowerBird	Socially networked, web-based biodiversity workspace for Australia. Allows projects to manage and develop their own workspaces for species sightings.	✓	✗	✗	✓	✗	✗	✗	Low	High	Free
CitSci.org	Portal to create citizen science projects. Includes tools to submit data, analyse data, share results, and obtain feedback from volunteers for program evaluation.	✓	✗	✗	✓	✓	?	?	Low	High	Free
GIS Cloud	A range of tools to allow field-data collection and mapping. Can be whitelabelled.	✓	✓	✓	✓	✓	?	✓	Low	High	$95/per month + $20 per device
Google Maps API	Suite of tools that allows data collection using online forms and Android mobile devices; and data submission to an online server.	✓	✗	✓	✓	✓	?	✓	High	Low	Free
iNaturalist	Portal to create citizen science projects. Observations can be logged online or from a mobile appl.	✓	✓	✓	✓	✓	✓	?	Low	High	Free
Spatial Vision Community Web Mapping Portal	Online portal for individuals and community groups to create, view and share information about their local landscape.	✓	✗	✗	✗	✓	?	?	Low	Low	Free
Ushahidi	Open-source platform that includes mapping tools and dynamic timeline. Allows information to be submitted by text, email, Twitter, and web-forms.	✓	✓	✓	?	✓	?	?	Low	High	Free

After Lambert (2014).

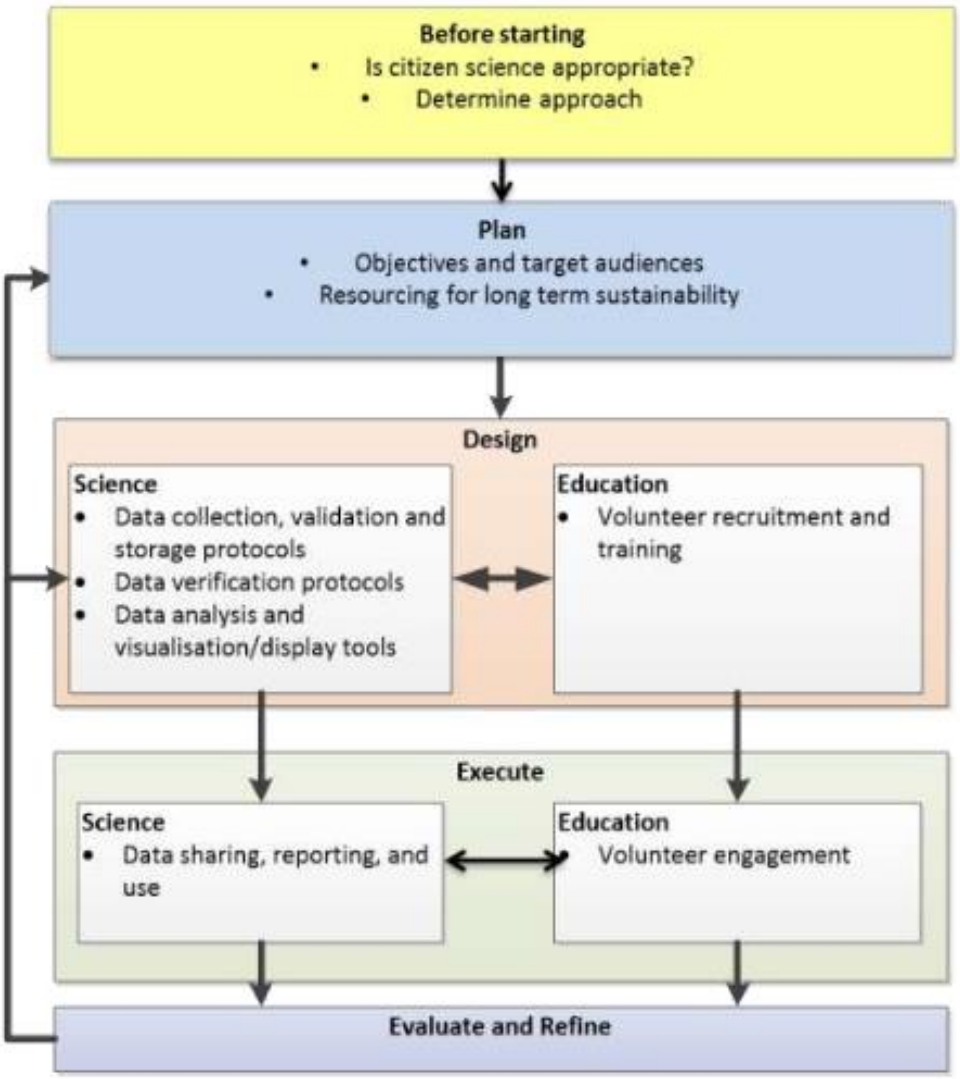
Appendix 6: Best practice frameworks for citizen science

a) Evaluation of project fit for citizen science (from Pocock et al. 2014)



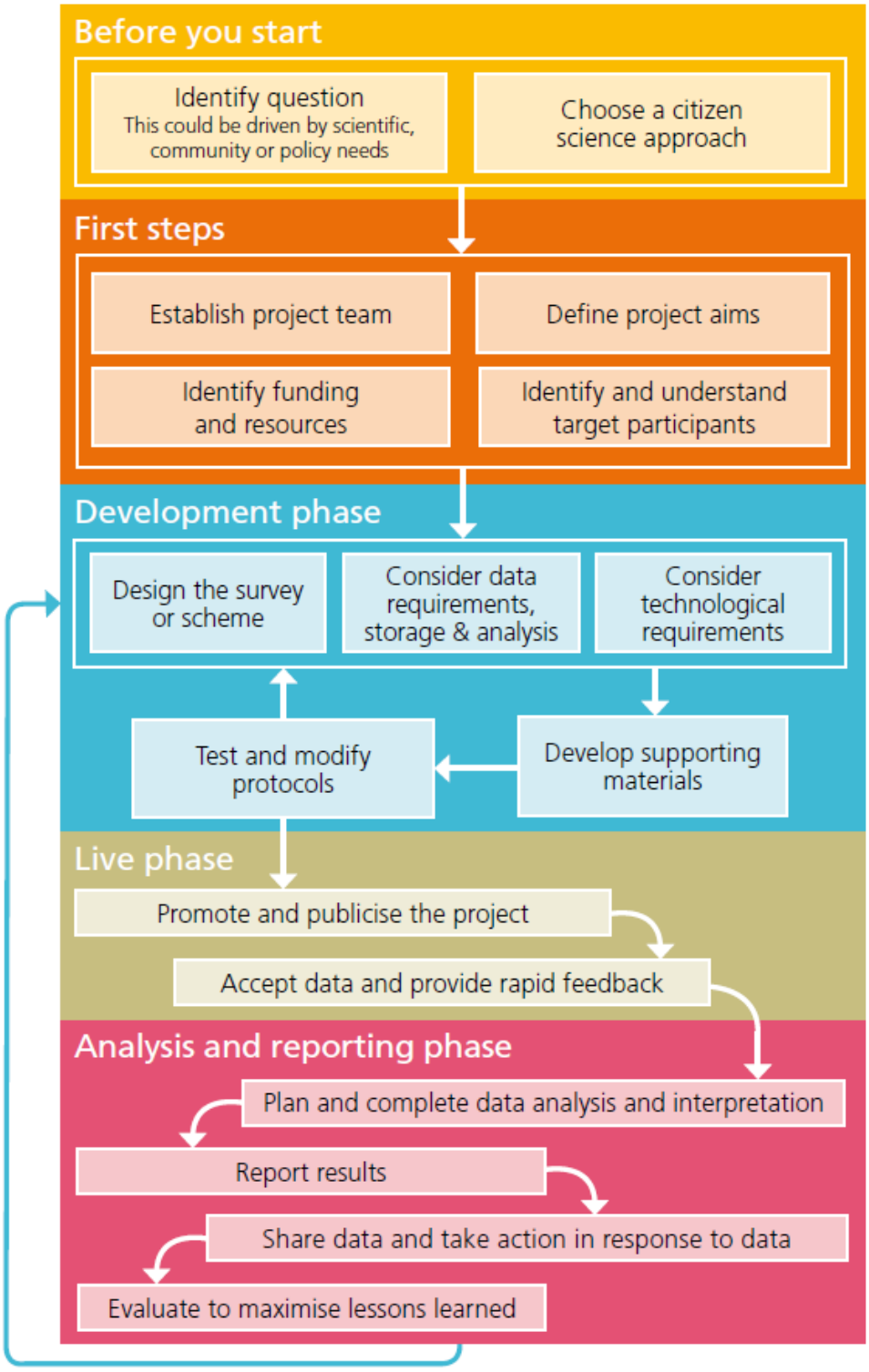

A
From Part 1
Short-term, large scale
Very worthwhile considering citizen science
Are there pre-selected sites (or special types of sites) that need to be visited?
NO
People can take part anywhere[5]
YES
Site accessibility: Are sites located where people are present/passing?
NO, so you need to incentivise visiting sites
Potentially suitable for a citizen science approach
YES
So you need to incentivise reporting
Is it easy to make a report/observation?
NO, needs time or special equipment
Not suitable for a citizen science approach
YES
Very good potential for a mass participation citizen science approach
Will the observation take just a moment or two and without the need for special equipment? (i.e. is the protocol simple?)
YES
NO
It will take longer
Is the 'protocol' easily learned and the subject easily accessed or ubiquitous?
NO
Usually not suitable for a citizen science approach
YES
Very good potential for a citizen science approach
B
From Part 1
Long-term, large scale
Worth considering citizen science
Can you work with volunteers who already have expertise?
NO
YES
Are you willing to develop the project with input from expert volunteers?
YES
Very good potential for a citizen science approach
NO[16]
Not suitable for a citizen science approach
C
From Part 1
Long-term, single site
Potentially worth considering citizen science
Are there groups of potentially interested people who could be recruited for the long-term
NO
Not suitable for a citizen science approach
YES
Is the protocol complex, or very prescriptive?
NO
Potentially suitable for a citizen science approach
YES
Are you willing to work with interested people and invest in training etc?
YES
Potentially suitable for a citizen science approach
NO
Not suitable for a citizen science approach

b) Project best practice framework (after Lambert 2014)



c) Project implementation framework (after Tweddle et al. 2012)

Once citizen science is selected as an appropriate approach, the following chart provides a useful guide to planning and implementing the project.



Appendix 7: Potential volunteer sources

Tier 1 – science skills and high-level experience

1. Retired scientists
2. Consultants – biological
3. Expert biologists/social scientists/geologists etc. (e.g., from Royal Society of Victoria, various associations)
4. University science faculty staff, students, and alumni
5. Traditional Owners.

Tier 2 – some science skills and experience

6. Field naturalists – South East Australian Naturalist Association (SEANA)
7. Friends groups (Victorian Environment Friends Network)
8. Staff, volunteers and friends of museums, zoos, botanic gardens, sanctuaries
9. Members of environment NGOs, Trust for Nature, Greening Australia
10. Members of existing citizen science projects
11. Federal, state, and local government employees with science qualifications.

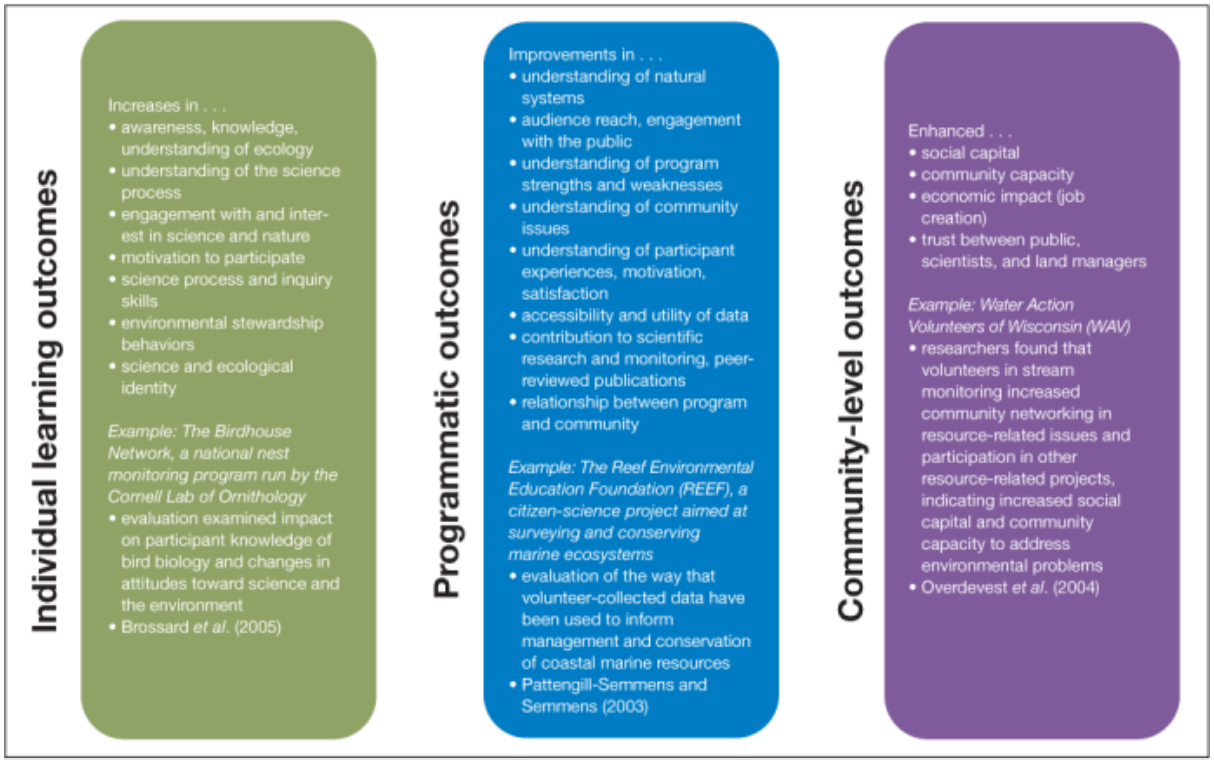
Tier 3 – large networks

12. Wildlife welfare organisations e.g., WIRES Australian Wildlife Rescue Association
13. Social networks (e.g., Landcare, *Land for Wildlife*)
14. Environmental education service providers: e.g., Port Phillip Eco Centre; Gould League, Dolphin Research Institute
15. Schools, Resource Smart Schools network
16. Sporting organisations (e.g., S.C.U.B.A. divers, fishing, hunting)
17. Motoring organisations (4WD clubs, auto clubs)
18. Parent and youth organisations, e.g., Cubs and Scouts, Roots & Shoots (Jane Goodall Institute)
19. Photography and art organisations
20. IT community
21. Local government.

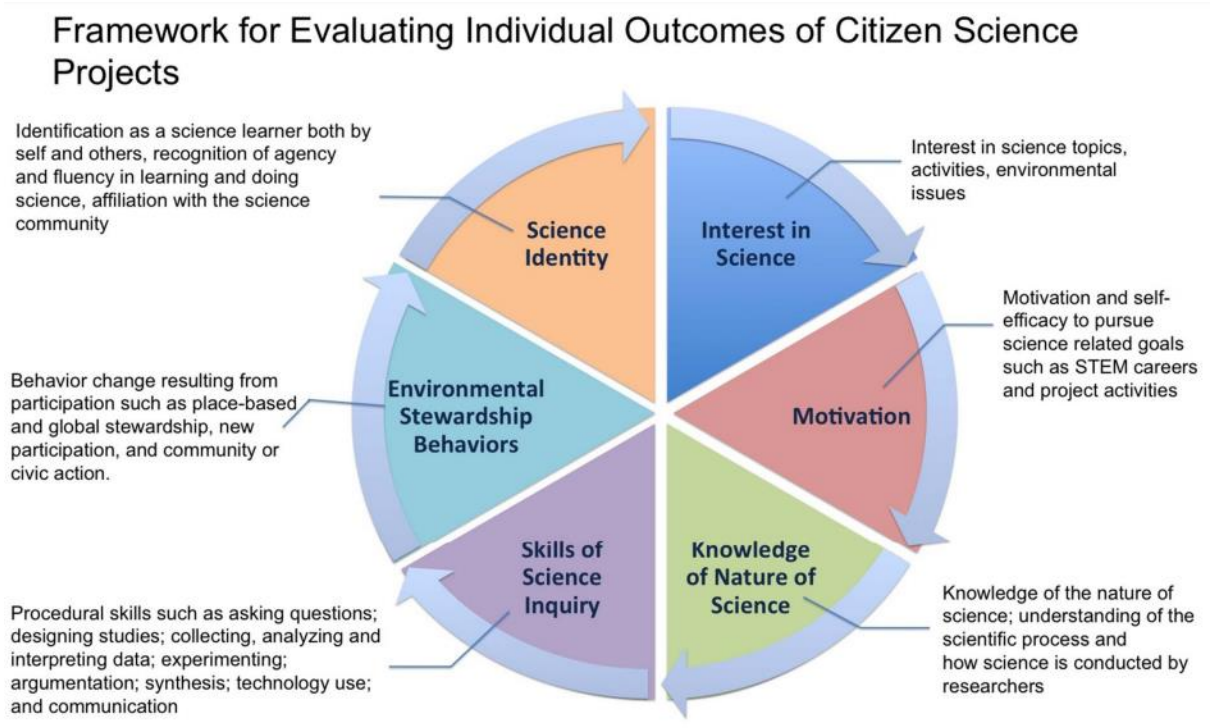
Tier 4 – general

22. General public
23. Staff of businesses/ organisations.

Appendix 8: Evaluation frameworks



After Jordan et al. (2012).



After Friedman (2008)

Appendix 9: Links to resources

Atlas of Living Australia – http://www.ala.org.au/get-involved/citizen-science/

See also Biocollect

Audubon Louisiana – http://la.audubon.org/get-involved/citizen-science

Aussie Backyard Bird Count – http://aussiebirdcount.org.au/

Register to count birds during one week in October. Includes an app.

Australian Citizen Science Association – https://citizenscience.org.au/

BioCollect – http://biocollect.ala.org.au/

A citizen science project finder initiated by the ACSA and managed by the Atlas of Living Australia. See also Atlas of Living Australia.

BiodivERsA Citizen Science Toolkit – https://www.biodiversa.eu/

BioQuisitive – http://www.bioquisitive.org.au/

'An open community laboratory, a safe environment for people from all walks of life to come and learn about biology, life sciences and get involved in workshops, classes and projects!'

Biosphere Expeditions – http://www.biosphere-expeditions.org/

Pay to participate in research.

BirdLife Australia Citizen Science – http://www.birdlife.org.au/get-involved/citizen-science/meet-our-citizen-scientists

Birdlife birdata portal – http://birdata.birdlife.org.au/

Bowerbird – http://www.bowerbird.org.au/

A Museum Victoria developed app that helps citizen scientists identify plants and animals, now integrated into iNaturalist.

BTO – https://www.bto.org/volunteer-surveys

British ornithology site with extensive volunteer opportunities and links to research.

CeRDI – http://www.vvb.org.au/vvb_map.php

Visualising Victoria's Biodiversity (VVB) – a place to discover and share spatial information on Victoria's environmental values, conservation activities and research.

Citizen Science Alliance – https://www.citizensciencealliance.org/

The CSA is a collaboration of scientists, software developers and educators who collectively develop, manage, and utilise internet-based citizen science projects in order to further science itself, and the public understanding of both science and the scientific process.

Citizen Science Central (Cornell) – http://www.birds.cornell.edu/citscitoolkit

See also Cornell labs citizen science.

Citizen Science Centre – http://www.citizensciencecenter.com/citizen-science-funding/

Personal blog site in the US.

Citizen Science.gov – https://www.citizenscience.gov/

U.S. federal government site providing resources and a list of projects.

CitSci.org – http://www.citsci.org/cwis438/websites/citsci/home.php?WebSiteID=7

Supports bottom-up project development by citizens.

Cornell labs citizen science – http://www.birds.cornell.edu/page.aspx?pid=1664

See also Citizen Science Central (Cornell).

Digivol – https://volunteer.ala.org.au/

Australian Museum site. Volunteers can transcribe historical documents, tag wildlife in photographs.

Do Something Near You – https://www.dosomethingnearyou.com.au/

National website for community volunteering and charities by postcode.

eMammal – https://emammal.si.edu/

USA – eMammal is a tool for collecting, archiving and sharing camera trapping images and data.

Entomological Society of Victoria – http://entsocvic.org.au/

Earthwatch Institute – http://au.earthwatch.org/scientific-research/our-approach-to-research-citizen-science

http://au.earthwatch.org/scientific-research/apply-for-funding

Support for research projects that contain citizen science elements.

European Citizen Science Association – http://ecsa.citizen-science.net/

Feralscan – https://www.feralscan.org.au/

For mapping feral animal sightings in your local area of Australia.

FrogID – https://www.frogid.net.au/

Frog Census – Melbourne Water – https://www.melbournewater.com.au/education/citizen-science/census/frog-census

GBIF http://www.gbif.org/

Global Biodiversity Information Facility. Free and open access to biodiversity data. ALA has been a member since 2001.

GEO BON – http://geobon.org/about/vision-goals/

International coordination of national biodiversity observation networks.

Happy Whale – https://www.happywhale.com/

Citizen scientists identify individual marine mammals.

iNaturalist – http://www.inaturalist.org/

Contribute sightings, assist with identification.

Indicia – http://www.indicia.org.uk/

For creating websites that facilitate the online recording of wildlife observations.

Lambert 2014 file:///C:/Users/Home/Downloads/Citizen-Science-Popes-Glen-Blue-Mountains.-Jane-Lambert-2014.pdf

Best practice guidelines for citizen science projects in Australia.

List of citizen science projects – https://en.wikipedia.org/wiki/List_of_citizen_science_projects

Wikipedia list of citizen science projects.

NatureMapper – http://naturemappingfoundation.org/natmap/

Washington State (USA) website resources (no longer active).

Nature Near Me – http://www.environment.nsw.gov.au/naturenearme/

NSW OEH app that allows people to comment on or rate natural places and share discoveries.

NatureShare – http://natureshare.org.au/

A 'citizen science' database for individuals and groups to document and share information about their local environment.

NatureWise EcoEscapes – http://naturewise.com.au/?_ga=1.73856914.1232344871.1479940130

Conservation Volunteers – http://conservationvolunteers.com.au/get-involved/holidays/

Holidays that involve contributing to conservation and research.

OEH NSW – http://www.environment.nsw.gov.au/research/citizenscience.htm

OPAL – https://www.opalexplorenature.org/

The Open-Air Laboratories (OPAL) network is a UK-wide citizen science initiative that allows you to get hands-on with nature, whatever your age, background, or level of ability. Funded by the Big Lottery Fund.

Pacific Conservation Institute – http://pacificbio.org/helpout/volunteer.html

Numerous volunteer projects. Details tasks.

Port Phillip Bay Ecocentre

http://www.ecocentre.com/

Questagame – http://portal.questagame.com/

An application to 'get players outdoors to discover and help preserve life on this planet'.

Reef Life Survey – http://reeflifesurvey.com/

International monitoring of marine species on reefs at local and other sites.

Royal Botanic Gardens Victoria – https://www.rbg.vic.gov.au/news/become-a-citizen-scientist

Scientific American – https://www.scientificamerican.com/citizen-science/

Connecting people and projects.

Scistarter – http://scistarter.com/about.html

SciStarter is the place to find, join, and contribute to science through more than 1600 formal and informal research projects and events. University of Arizona.

SEANA – http://environmentvictoria.org.au/group-member/south-east-australian-naturalist-association/

Southeast Australian Naturalists Association.

Sherbrooke Lyrebird Study Group – http://sherbrookelyrebirdstudygroup.blogspot.com.au/p/about-us.html

Snapshot Serengeti – https://www.snapshotserengeti.org/

Camera trap images.

Socientize (Horizon 2020) – https://ec.europa.eu/programmes/horizon2020/en/news/every-citizen-scientist-eu-project-tries-change-face-research

A citizen science program within the European Union's science investment initiative Horizon 2020.

SWIFFT – http://www.swifft.net.au/

Statewide Flora and Fauna Teams is a network for sharing biodiversity knowledge, observations, projects, current events, ideas, and access information from experts in their field.

Texas Estuarine Resource Network – http://tx.audubon.org/conservation/tern-citizen-science

Theory and Practice of Citizen Science – http://theoryandpractice.citizenscienceassociation.org/

Citizen science journal initiated in 2016.

US Phenology Network – https://www.usanpn.org/

https://www.pwrc.usgs.gov/bpp/index.cfm

Victorian Environment Friends Network – http://vnpa.org.au/page/volunteer/victorian-environment-friends-network

VNPA (citizen science) – http://vnpa.org.au/page/volunteer/citizen-science

Waterwatch Portal – http://www.vic.waterwatch.org.au/

Waterwatch is a citizen science program for monitoring waterway health.

Wildlife Spotter – https://wildlifespotter.net.au/

To assist researchers by looking for animals in wilderness photos taken by automated cameras around Australia. Supported by the ABC.

Victoria's Volunteering Portal – http://www.volunteer.vic.gov.au/

Visualizing Victoria's Biodiversity

http://www.vvb.org.au/vvb_map.php

'a place to discover and share spatial information on Victoria's environmental values, conservation activities and research'.

Volunteering Victoria – http://volunteeringvictoria.org.au/

Peak body for volunteering in Victoria. Links to local volunteer coordinators.

Zooniverse – https://www.zooniverse.org/

A platform for people-powered research.

Appendix 10: Project checklist

Key considerations:

- Are there appropriate resources available to effectively engage people?
- Can you provide adequate training?
- How much data do you need?
- What is the geographic and temporal scale?
- Can the task/s be readily undertaken, logistically, physically, safely, accurately?
- Can you demonstrate how the data will be used?
- Can you work with other similar existing projects or do you need a completely new project?
- Can you provide meaningful feedback, in suitable formats and frequencies?

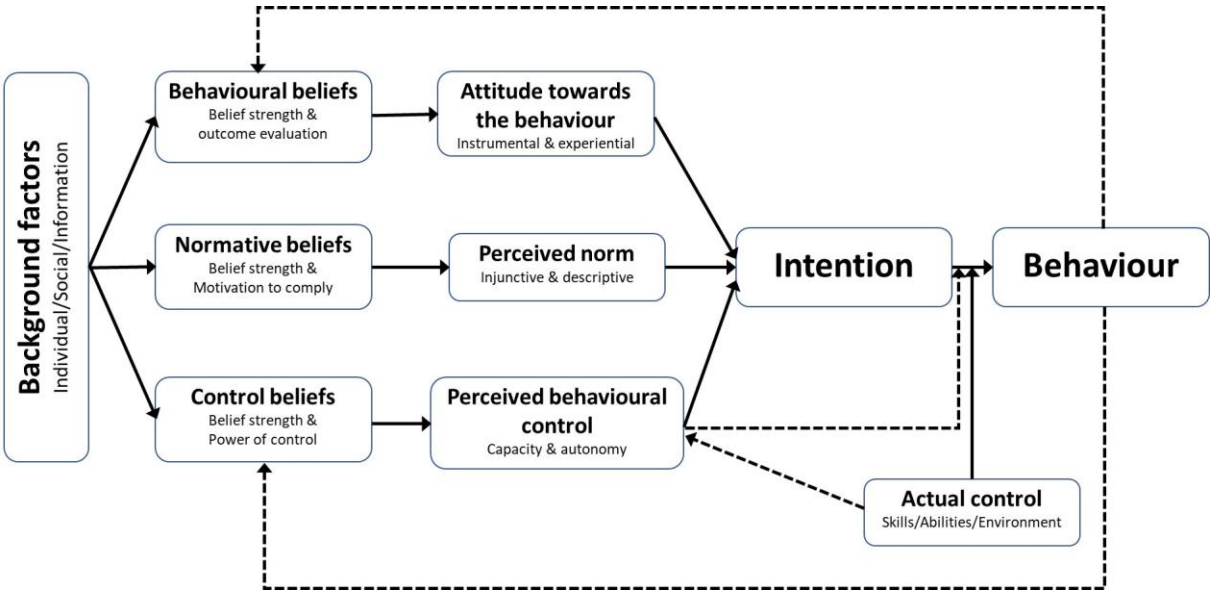
Best practice:

Citizen science works best when:

- it benefits all parties
- the aims, the questions, the tasks and different roles and responsibilities are all precise and clearly defined and communicated at the beginning
- the project involves skill/expertise in communication, as well as design, data collection and analysis
- participants feel part of the team, understand the value and relevance of their role, and learn new skills
- the tasks are simple, the project is fun, and citizen science is an efficient way to gather (and sometimes analyse) the data
- there are clear 'triggers' for gathering data
- the quality of the data generated is measurable
- evaluation is included, and adaptation is possible
- scientists and citizens work alongside each other for at least part of the time
- projects begin with a small-scale trial, and can be scaled up if/as required
- participants are carefully targeted, supported, regularly informed about their contribution, and highly motivated
- motivations and skillsets of all parties are understood
- participants' inputs are well recognised and acknowledged, including in relevant publications
- communication, training, and feedback are all adequately resourced.

Appendix 11: Behavioural change model for citizen science

Theory of Planned Behaviour (in Martin 2016b)



Appendix 12: Technologies and their role in supporting citizen science

Connecting people with projects and organisations	Project planning/toolkits	Collecting data (forms, laboratory facilities)	Managing and storing data and identifying species	Training resources	Feedback (maps, stats etc.)
Australian Association for Citizen Science https://citizenscience.org.au Atlas of Living Australia http://biocollect.ala.org.au/ US Citizen Science (Federal Govt) https://ccsinventory.wilsoncenter.org/ Wikipedia https://en.wikipedia.org/wiki/List_of_citizen_science_projects Scientific American https://www.scientificamerican.com/citizen-science/ Scistarter http://scistarter.com/about.html SWIFFT http://www.swifft.net.au/	US Citizen Science Toolkit https://crowdsourcing-toolkit.sites.usa.gov/ CitSci http://www.citsci.org/cwis438/websites/citsci/home.php?WebSiteID=7 BiodivERsA Citizen Science Toolkit https://www.biodiversa.org/1814	BioCollect http://www.ala.org.au/biocollect/ Superb Parrot mobile app http://root.ala.org.au/bdrs-core/oeh-sp/home.htm Bioquisitive (laboratory) http://www.bioquisitive.org.au/ Birdata http://birdata.birdlife.org.au/ eBird https://secure.birds.cornell.edu/cassso/login? FrogID https://www.frogid.net.au/ CitSci http://www.citsci.org/cwis438/websites/citsci/home.php?WebSiteID=7 Sapelli https://www.ucl.ac.uk/excites/software/sapelli INaturalist http://www.inaturalist.org/	Bowerbird Project on iNaturalist https://www.inaturalist.org/projects/bowerbird Visualising Victoria's Biodiversity http://www.vvb.org.au/vvb_map.php Victorian Biodiversity Atlas - VBA Go https://www.environment.vic.gov.au/biodiversity/victorian-biodiversity-atlas/vba-go Atlas of Living Australia https://auth.ala.org.au/cas/login?service=http%3A%2F%2Fsightings.ala.org.au%2F Geokey (mapping software) – http://geokey.org.uk/ Feralscan (mapping feral animals) https://www.feralscan.org.au/ Natureshare (record species/sites, incl. invertebrates) http://natureshare.org.au/	eMammal Academy (camera trapping training) https://emammal.si.edu/content/emammal-academy Cornell Labs – http://www.birds.cornell.edu/ Citizen Science Association (US) http://citizenscience.org/2016/07/26/educators-citizen-science-training-opportunities/	Birdata http://birdata.birdlife.org.au/ eMammal https://emammal.si.edu/projects Happy Whale map https://www.happywhale.com/browse?view=map Moth Tracker https://www.swifft.net.au/mothtracker/

Connecting people with projects and organisations	Project planning/toolkits	Collecting data (forms, laboratory facilities)	Managing and storing data and identifying species	Training resources	Feedback (maps, stats etc.)
Zooniverse https://www.zooniverse.org/about		Indicia (website forms) http://www.indicia.org.uk/	Reef life survey http://reeflifesurvey.com/		

www.delwp.vic.gov.au

www.ari.vic.gov.au