Citizen Science for Flora and Fauna Conservation: Ensuring Success

Jane Lambert z3435484

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Executive Summary

The research aims to provide a best-practice framework for flora and fauna conservation citizen science projects in Australia.

The use of citizen science in conservation projects is rapidly expanding. As illustrated by examples from North America and Europe, citizen science can significantly contribute to scientific knowledge, as well as increasing public engagement and awareness of conservation issues.

Low-cost technology tools have spurred the recent growth of the field. However, projects still face considerable challenges – including ensuring data integrity, maintaining volunteer interest and maximising research use.

I argue that projects can address these issues by following a best practice framework that includes 10 key elements:

1. Project approach
2. Objectives and target audience
3. Resourcing for long term sustainability
4. Data collection protocols
5. Data verification protocols
6. Data analysis, display and reporting
7. Information dissemination and use
8. Publicity and volunteer recruitment
9. Volunteer engagement
10. Project evaluation

To illustrate the framework in action, I use it as:

- An assessment tool for Popes Glen Bushcare Group's established citizen science project
- A planning tool for Science4Wildlife's (S4W) embryonic citizen science program

This framework was developed through a literature review of case studies published in academic journals and augmented with non-academic sources found through Google and Twitter.

The results show that citizen science shows great potential for achieving conservation outcomes. However, the collective impact of the field will remain limited without appropriate institutional-level change. This includes scientist and policymaker acceptance of the validity of citizen science, centralised technology platforms, standardised evaluation methodologies, and network support.

Background

Citizen science involves scientists partnering with members of the public to conduct research. Some scholars propose the use of the alternative "public participation in scientific research" as a more integrated term to encourage collaboration (Shirk *et al.* 2012).

Emerging as a distinct field over the last 20 years, citizen science can be differentiated from other forms of public participation by the active role taken by volunteers.

Citizen science is now enjoying a boom, as illustrated by the 300% increase in Google searches for "citizen science" since 2009 (Figure 1).

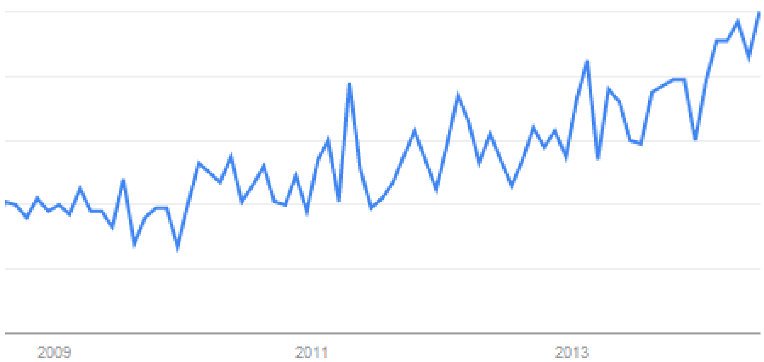

Figure 1 – Searches for "citizen science" since 2009 (google.com.au/trends)

This is due to:

- An increasing realisation that citizens can provide a valuable, low cost way to advance scientific knowledge
- The ability of citizen science to provide educational benefits
- The increasing availability of low-cost technological tools to support citizen science projects

Whilst citizen science shows great potential for improving conservation outcomes, the field is expanding so rapidly that most projects are following a "learning by doing approach" that lacks methodological rigour. This is particularly true in Australia, where the field has had less time to mature compared to North America and Europe.

Research Aims and Approach

This research aims to provide guidelines to help citizen science projects realise their potential benefits. This focus is on local-scale flora and fauna conservation projects in Australia; however, many lessons are drawn from successful larger-scale (and international) projects.

The research seeks to answer the following questions:

- How can citizen science contribute to addressing conservation issues?
- How have flora and fauna conservation projects – nationally and internationally – used citizen science?
- What are the trends in its application?

- What are its successes?
- What are the barriers and limitations?
- What factors are critical to success?
- Can citizen science be used to achieve both scientific and educational goals?

To answer these questions, I reviewed existing literature available on citizen science projects.

A literature search was conducted on Google Scholar and Thomson Reuters Web of Science using the phrases "citizen science", and "public participation in scientific research". Additional literature was found through the reference lists of articles.

As citizen science is such a new field, many initiatives are not documented in peer-reviewed literature. Websites and Government reports were also sourced using the phrase "citizen science" on Google.com.au and the hashtag #citizenscience on Twitter. Search results were prioritised based on relevance and currency.

I developed a best practice framework for citizen science projects by conducting a thematic analysis of the peer-reviewed literature and extracting the most frequently cited recommendations (Table 1).

This framework was tested through application to two case studies from the Greater Blue Mountains World Heritage Area:

- Popes Glen Bushcare Group existing citizen science project
- Science4Wildlife's embryonic citizen science project

Information for the case studies was collected through interviews and email correspondence with the project coordinators.

Table 1 - Concept Matrix: Best practice recommendations for citizen science as listed in the peer reviewed literature (grouped into three main categories by the report author)

Themes / References	Advancing scientific knowledge								Education and public engagement							Project governance					
	Data collection protocols	Statistical sampling / analysis methods	Training and support materials	Data validation and verification	Data management and analysis	Data sharing	Data visualisation	Data publication	Recruitment strategies	Partnerships	Ongoing communication with volunteers	Rewards / feedback for participation	Active learning / communications	Collaboration / 2 way communication	Link to future actions	Explicit objectives and data uses	Model / Framework	Planning	Multiple revenue streams	Personnel / human resources	Project Evaluation
Bonney et al. 2009a			✔	✔							✔	✔			✔		✔	✔			✔
Bonney et al. 2009b	✔		✔	✔			✔	✔		✔							✔	✔		✔	✔
Brossard et al. 2005															✔						✔
Conrad & Hilchey 2009	✔		✔							✔		✔		✔							
Crall et al. 2010	✔			✔		✔	✔														
Davies et al. 2011	✔		✔	✔		✔	✔		✔			✔									
DeVictor et al. 2010															✔	✔					
Dickinson et al. 2012			✔					✔	✔	✔							✔	✔			
Dickinson et al. 2010	✔		✔	✔																	
Evans et al. 2005											✔		✔	✔	✔						
Gallo et al. 2011	✔		✔	✔			✔			✔	✔			✔							
Hardisty et al. 2013	✔		✔			✔		✔													
Haywood & Besley 2013																✔	✔				✔
Hobbs & White, 2012									✔	✔											
Hochachka et al. 2011	✔	✔	✔	✔																	
James 2011	✔	✔	✔	✔	✔	✔		✔	✔		✔					✔		✔	✔	✔	
Jiguet et al. 2012	✔		✔				✔				✔	✔									
Jordan et al. 2011													✔	✔	✔						
McKinley et al. 2012			✔											✔							
Newell et al. 2012	✔													✔							
Newman et al. 2010						✔	✔						✔	✔							
Newman et al. 2012							✔						✔	✔							✔
Rotman et al. 2012													✔		✔						
Roy et al. 2012	✔		✔	✔		✔	✔			✔						✔			✔	✔	
Shirk et al. 2012																	✔	✔			
Silvertown 2009	✔							✔				✔									
Sullivan et al. 2014	✔		✔	✔		✔	✔	✔			✔	✔	✔	✔							
Toomey & Domroese 2013															✔						
Tulloch et al. 2013						✔					✔					✔					
Tweddle et al. 2012	✔		✔	✔				✔	✔	✔	✔	✔				✔	✔	✔	✔	✔	✔
Wiggins & Crowston 2011																			✔		
Count	15	2	15	11	1	8	9	7	5	7	8	7	6	9	7	6	6	6	4	4	6

Results

Uses and Benefits of Citizen Science

Advancing Scientific Knowledge

Many ecological processes occur over large spatial and temporal scales, including migration patterns, disease spread, and species range changes (Bonney *et al.* 2009). Gathering sufficient data on such processes is impossible using traditional research methods – particularly given limited time and funds (Tulloch *et al.* 2013, Dickinson *et al.* 2010). Recruiting volunteer researchers from the general public offers a low cost way to expand the reach and frequency of data collection.

The power of citizen science to collect vast amounts of ecological data is well illustrated by eBird, established by the Cornell Lab of Ornithology in 2002 to collect information on bird abundance and distribution[1]. Through a combination of community engagement and partnerships, eBird has created a global network of volunteers who submit an average of 3 million observations per month (Sullivan 2014).

Citizen science projects have also used successfully intensive data collection techniques, such as BioBlitzs – field surveys that aim to record all the living species within a designated area over a specific time period.

The longest running BioBlitz is the National Audobon Society's Annual Christmas Bird Count[2]. Each year up to 80,000 volunteer birdwatchers collect data on bird observations over 1 day in the Christmas period (Silvertown 2009). This program is a major source of information on North America's bird species, providing long-term population data over a vast geographic range (Silvertown 2009).

A number of BioBlitzs have been implemented in Australia, including the University of South Australia's Operations Spider, Magpie, and Possum (UniSA 2013), the 2013 ACT Centenary BioBlitz, and the Great Koala Count South Australia (UniSA 2012) and New South Wales (N.P.A 2013, Cleary 2014). Over 10 days in November 2013, the N.S.W Great Koala Count invited members of the public to survey their local environments and record koala sightings on the project's website or smart phone application (N.P.A 2013). Almost 1000 records were received from citizen scientists and entered into the Atlas of Living Australia to form part of Australia's biodiversity record (Cleary 2014).

With its "many eyes", citizen science is an effective way to find rare species (Dickinson *et al.* 2012). Intrepid citizen scientists rediscovered a species of ladybug (*Cocinella novemnotata*) in New York State that was presumed locally extinct (Losey *et al.* 2007). A recent EcoBlitz[3] conducted by scientists and school students in New Zealand claims to have discovered a new species of native invertebrate (Lincoln University 2014).

Citizen science shows promise as a way to track the spread of invasive species, as illustrated by numerous examples of weed tracking networks in North America, e.g. the 'Invaders of Texas' (Gallo & Waitt 2011) and 'Spotting the weedy invasives' (Bonney *et al.* 2009a, Jordan *et al.* 2012). In Australia, this approach is used by FeralScan[4] to track the spread of pest fauna species – including rabbits, camels, foxes, cane toads and starlings.

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[1] See www.ebird.org
[2] See www.birds.audubon.org/christmas-bird-count
[3] A BioBlitz tries to build a large species list from one place in a limited period. The Nina Valley EcoBlitz differed in that students collected their observations using standard ecological sampling methods, under the guidance of expert scientists, so that their data can be used to help monitor ecological changes (Whitelaw 2014).
[4] See www.feralscan.org.au

Data collected from citizens is frequently used to produce biodiversity indicators – vital tools to inform management, resource allocation, policy and planning (Devictor *et al.* 2010*,* Tulloch *et al.* 2013). For example, breeding bird survey data provide input for the Farmland Bird Index, adopted by the European Union as a structural indicator of sustainable development (Jiguet 2012). This provides a cost-effective alternative to government monitoring. Levrel *et al.* (2010) estimate that citizen-led breeding bird surveys save the French government up to €770,000 per year.

Education and Public Engagement

Many conservation issues have social roots (Jordan *et al.* 2011). However, the Australian public's awareness of these issues is low and further diminishing (N.S.W OEH 2013).

Engaging the public in the scientific research process can help address this issue. Citizen science can increase scientific literacy, encourage pro-environmental attitudes and behaviours, and promote active engagement in policy-making. The ability to connect science research to educational outcomes is often crucial in obtaining funding grants (Silvertown 2009).

Many citizen science projects have explicit educational goals. For example, OPAL – a U.K.-wide citizen science initiative encompassing a range of biological monitoring activities – aims to "encourage more people to spend time outside exploring and recording the world around them" (Davies *et al.* 2011).

Volunteer education is often delivered as online and/or hard copy documentation covering the aims of the study and explaining how to carry out observations. Many citizen science projects also target students from local schools. For example, Museum Victoria's Biodiversity Snapshots recruits students and teachers to report local fauna observed during school field trips (M.V. 2014)

Numerous studies show that involvement in citizen science projects can increase volunteers' knowledge of ecological systems. The evaluation by Jordan *et al*. (2011) of an invasive plant-monitoring project reported that volunteer's knowledge of invasive plants increased on average by 24%. Similarly, the evaluation by Evans *et al*. (2005) of 'The Neighborhood Nestwatch Program' found that volunteers increased their knowledge of avian ecology.

Some authors also cite the potential of citizen science to engage volunteers in conservation actions by developing pro-environmental attitudes and behaviours (Toomey *et al.* 2013*,* Conrad & Hilchey 2011). Volunteers involved in the 'Monarch Larvae Monitoring Project' reported that the project led them to take an active role in habitat improvement (Oberhauser & Prysby 2008). Similarly, the evaluation by Crall *et al.* (2012) of an invasive plant species program reported significant changes in volunteer behaviour – including controlling invasive species and educating others about invasive species.

Citizen science may also provide other social benefits that are difficult to measure. A review of community-based forest management projects showed they can improve communication and lead to shared ecological goals between diverse stakeholder groups (Fernandez-Gimenez *et al.* 2008). Conrad & Hilchey (2011) argue that citizens in areas with community monitoring activities tend to be more engaged in local issues, participate more in community development and have more influence on policy-makers.

Types and Trends

The domain of citizen science projects is rapidly expanding. Citizens can now participate in projects on climate change, conservation biology, ecological restoration, population ecology and monitoring of all kinds (Dickinson et al. 2012, Roy *et al.* 2012).

Approaches to citizen science are also diverse, leading Bonney *et al.* (2009a) to propose a typology that classifies project according to their degree of public participation; and Wiggins & Crowston (2011) to classify projects based on their goals (Table 2)

Table 2 – Project Typologies

Bonney *et al.* (2009a) typology	
Type	**Description**
Contributory	Designed by scientists, volunteers primarily contribute data
Collaborative	Designed by scientists, volunteers contribute data, refine project design, analyse data, disseminate findings
Co-created projects	Co-designed by scientists and volunteers

Wiggins & Crowston (2011) typology	
Type	**Description**
Action	Citizens collaborate with scientists in action research approaches, often to address local environmental concerns
Conservation	Focus on protecting and managing natural resources whilst educating the public
Investigation	Focus on testing specific research hypotheses
Virtual	May have similar goals, but all activities are carried out remotely, using online platforms
Education projects	Primarily conducted to achieve educational goals (scientific rigour may be less important)

Different project approaches reflect a different balance between scientific and educational goals, and varying levels of volunteer engagement. Examples of project types are shown in Table 3.

Table 3 - Examples of citizen science projects and their classifications

I classified a selection of projects based on the typologies of Bonney *et al.* (2009a) and Wiggins & Crowston 2011. Though this is far from being a complete list of citizen science projects, it is safe to conclude that the vast majority of projects cited in the literature are 'contributory'. Less information is available on 'action' and 'co-created' projects, as these tend to be small-scale and community focused.

Project	Location	Bonney *et al.* (2009a) typology	Wiggins & Crowston (2011) typology	Purpose	Website
FeralScan	Australia	Contributory	Conservation	Locating invasive fauna	www.feralscan.org
Great Koala Count NSW	NSW, Australia	Contributory	Conservation	Locating native fauna	www.koalacount.ala.org.au/bdrs-core/npansw/home.htm
Biodiversity snapshots	Victoria, Australia	Contributory	Education	Biodiversity surveys	www.biodiversitysnapshots.net.au/
ClimateWatch	Australia	Contributory	Investigation	Monitoring phenology (seasonal life cycles)	www.climatewatch.org.au
Streamwatch	Sydney, Australia	Co-created	Conservation	Monitoring local stream health	www.streamwatch.org.au
Coastal Walkabout	Western Australia	Collaborative	Conservation	Monitoring coastal biodiversity	www.coastalwalkabout.gaiaresources.com.au/
Birds in Backyards	Australia	Contributory	Conservation	Collecting bird observations	www.birdsinbackyards.net/
Explore the Sea Floor	Australia	Contributory	Virtual	Classifying marine organisms	www.exploretheseafloor.net.au/
Monarch Larva Monitoring Program	United States and Canada	Contributory	Investigation	Collecting monarch butterfly distribution data	www.mlmp.org
OPAL	United Kingdom	Contributory	Investigation	Monitoring water, air, soil, biodiversity, bugs, climate	www.opalexplorenature.org
French Breeding Bird Survey	France	Contributory	Investigation	Collecting bird observations	www.vigienature.mnhn.fr/page/oiseaux
The Invaders of Texas	Texas, USA	Collaborative	Conservation	Locating and managing invasive plants	www.texasinvasives.org/
The Great Christmas Bird Count	United States and Canada	Contributory	Investigation	Collecting bird observations	www.birds.audubon.org/Christmas-bird-count
Project BudBurst	United States	Contributory	Investigation	Monitoring phenology (seasonal life cycles)	www.budburst.org
Celebrate Urban Birds	United States and Canada	Contributory	Conservation	Collecting bird observations	www.celebrateurbanbirds.org
Sherman's Creek Conservation Association	Sherman's Creek, PA, USA	Co-created	Action	Protecting local creek	www.shermanscreek.org
Invasive Plant Atlas of New England	New England, USA	Collaborative	Conservation	Mapping invasive plants	www.ipane.org
eBird	Global	Contributory	Investigation	Collecting bird observations	www.eBird.org

Advances in communication technology have underpinned the proliferation of citizen science projects. Online, social media, smart phone and Geographical Information System (GIS) tools allow projects to engage broad audiences, motivate volunteers and improve data collection.

Online forms enable the collection of large volumes of data that can be verified in real time and submitted to shared databases. This information was previously collected using postal surveys, which suffer from low response rates and high cost. Websites can also provide promotional content, training materials, display data and collect volunteer feedback (Roy *et al.* 2012).

A variety of open-source online tools allow free website creation and maintenance, including content management systems (e.g. Drupal), blog platforms (e.g. WordPress) and online survey tools (e.g. SurveyMonkey).

A number of end-to-end online citizen science platforms are also now available. The most comprehensive of these is the U.K.'s Indicia, which provides a base kit for website construction – including recording forms, maps and record verification. Almost 50 monitoring projects are now using the Indicia platform (Lightfoot 2013).

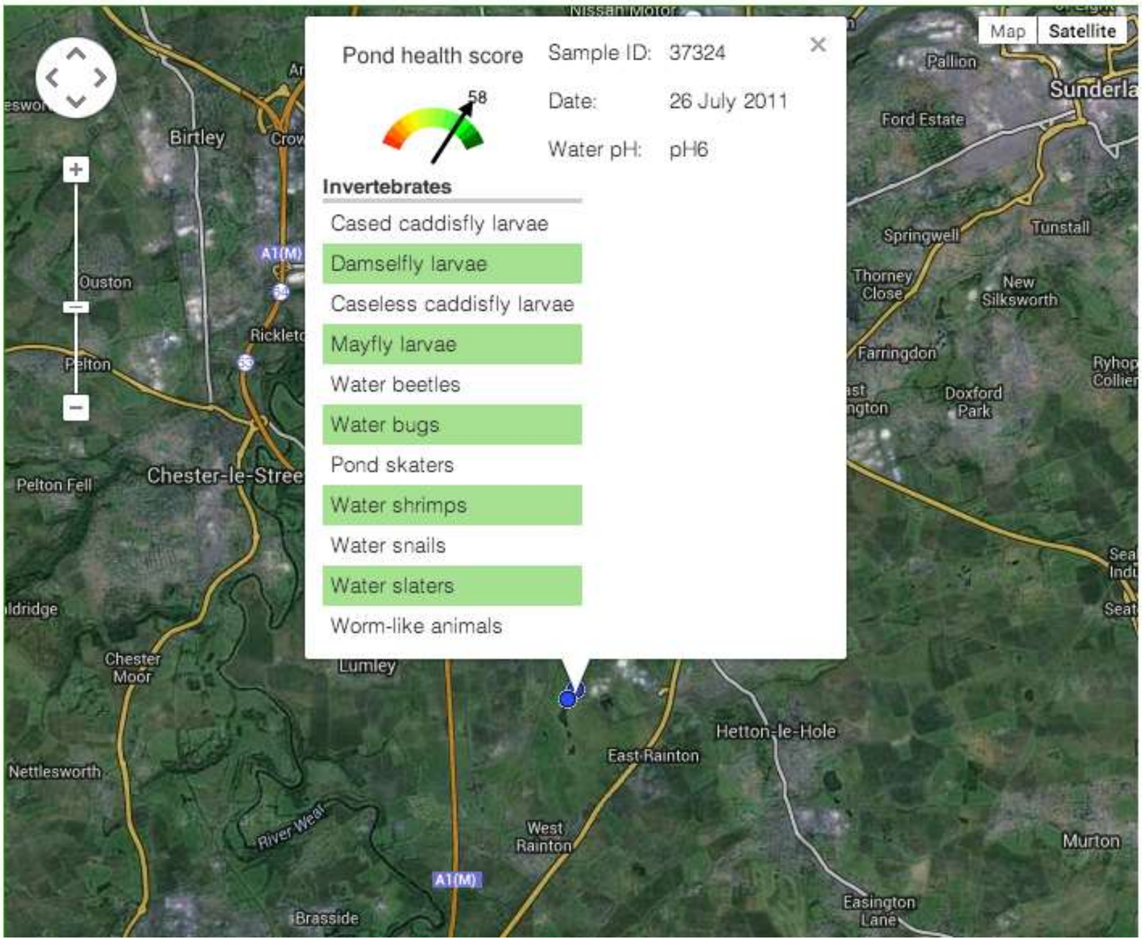
Similarly, the Atlas of Living Australia's FieldData software is an open source plug-in that can provide data collection and management facilities. FieldData is used by Museum Victoria's Biodiversity Snapshots, the Great Koala Count, the ACT Centenary BioBlitz and many other projects (A.L.A 2014).

The ubiquity of smart phones has also increased the reach and accuracy of citizen science data collection. Observations can be validated through the upload of photos, and GPS chips provide automatic location sensing (Hochachka 2012). The smart phone application used by Project BudBurst captures the observer's location, provides a simple data entry form with standardised definitions, and includes a game to motivate volunteers (Newman *et al.* 2012) (Figure 2).

Figure 2 - Screen capture of the Project BudBurst mobile application

A range of GIS tools can visualise data in real time. This can motivate volunteers by allowing them to understand project activities, interpret the data and view their own contributions (Roy *et al.* 2012). Google Maps is the most commonly used tool for this purpose (Roy *et al.* 2012), and may be combined with graphs to allow easier interpretation of data (Figure 3).

Figure 3 - OPAL water invertebrate survey map and chart



Social media tools can also be used for volunteer outreach and engagement. For example, 'The Garden Bioblitz' used Twitter, Instagram and Flickr to provide rapid feedback to volunteers and build an online community (Roy *et al.* 2012).

Whilst these technological advances are exciting, they can also exclude some audience segments. For example, older demographics may not have access to particular technologies such as smart phones, or may not use social media tools such as Facebook. Data collection methods must match each project's target audience.

Challenges

Whilst the multitude of citizen science projects existing today show great potential for collectively improving ecological knowledge, most face challenges in terms of data quality, utility (i.e. how data is used), organisational constraints and volunteer empowerment (Roy *et al.* 2011, Dickinson *et al.* 2012, Hochachka 2012).

Many scientists express concern about data collected by volunteers (Gollan *et al.* 2012, Sequeira *et al.* 2014). Potential errors include biased sampling (non-random site selection), incorrect estimates of species abundance and misidentification of inconspicuous species (Cooper *et al.* 2012; Crall *et al.* 2010)

Compounding this issue, many citizen science projects lack the resources to perform data quality procedures, including volunteer training and expert validation of species identification. Only 39% of the invasive species monitoring projects evaluated Crall *et al* (2010) had data quality checks in place. Data checking procedures are critical for 'investigation' and 'conservation' projects; they may be less critical for 'action' and 'education' projects.

Data collected by citizen science initiatives may not be adequately analysed or shared with other groups. Only 64% of the invasive species monitoring programs reviewed by Crall *et al.* (2010) generated species distribution maps and only 23% made their data publicly available, due to concerns about privacy and data sensitivity. Few projects have clear data ownership policies, or inform volunteers about intellectual property rights (E.C. 2014).

Data collected by citizen scientists may not be taken seriously. Many groups find their results are not used in the decision-making process or published in peer-reviewed journals (Wiggins & Crowston 2011, Conrad & Daoust 2008). Despite a growing body of literature showing that data collected by citizens can be comparable to those of professional scientists (Gollan *et al*. 2012, Vianna *et al*. 2014), many scientists and policymakers still question data integrity. For example, Newell (2012) found that a project tracking the spread of cane toads in northern N.S.W met with resistance from conservation managers within government departments – due to mistrust of data collected by non-experts.

Organisational issues faced by citizen science projects include funding and resource limitations. Many projects rely on short-term grants, presenting a barrier to long-term sustainability (Crall *et al.* 2010). Technology may also be a burden, with volunteers lacking the time to develop and maintain infrastructure and content (Wiggins & Crowston 2011).

Generating and maintaining volunteer interest is also a key challenge, as illustrated by difficulties faced by the N.S.W Great Koala Count (Cleary 2014). Volunteers' motivations are complex, change throughout the project lifecycle and are strongly affected by personal interests (Rotman *et al.* 2012).

It is difficult to establish clear links between citizen science activities and their impact on volunteer attitudes and behaviour. Few projects have rigorously assessed this connection, which is difficult to measure – especially as volunteers are likely to have more pro-environmental attitudes than the general public (Jordan *et al.* 2011*,* Toomey *et al.* 2013). As argued by Jordan *et al.* (2011), Crall *et al*. (2012) and Toomey *et al.* (2013), further research is required to measure and document impacts in terms of actual changes in behaviour, supported by appropriate evaluation instruments.

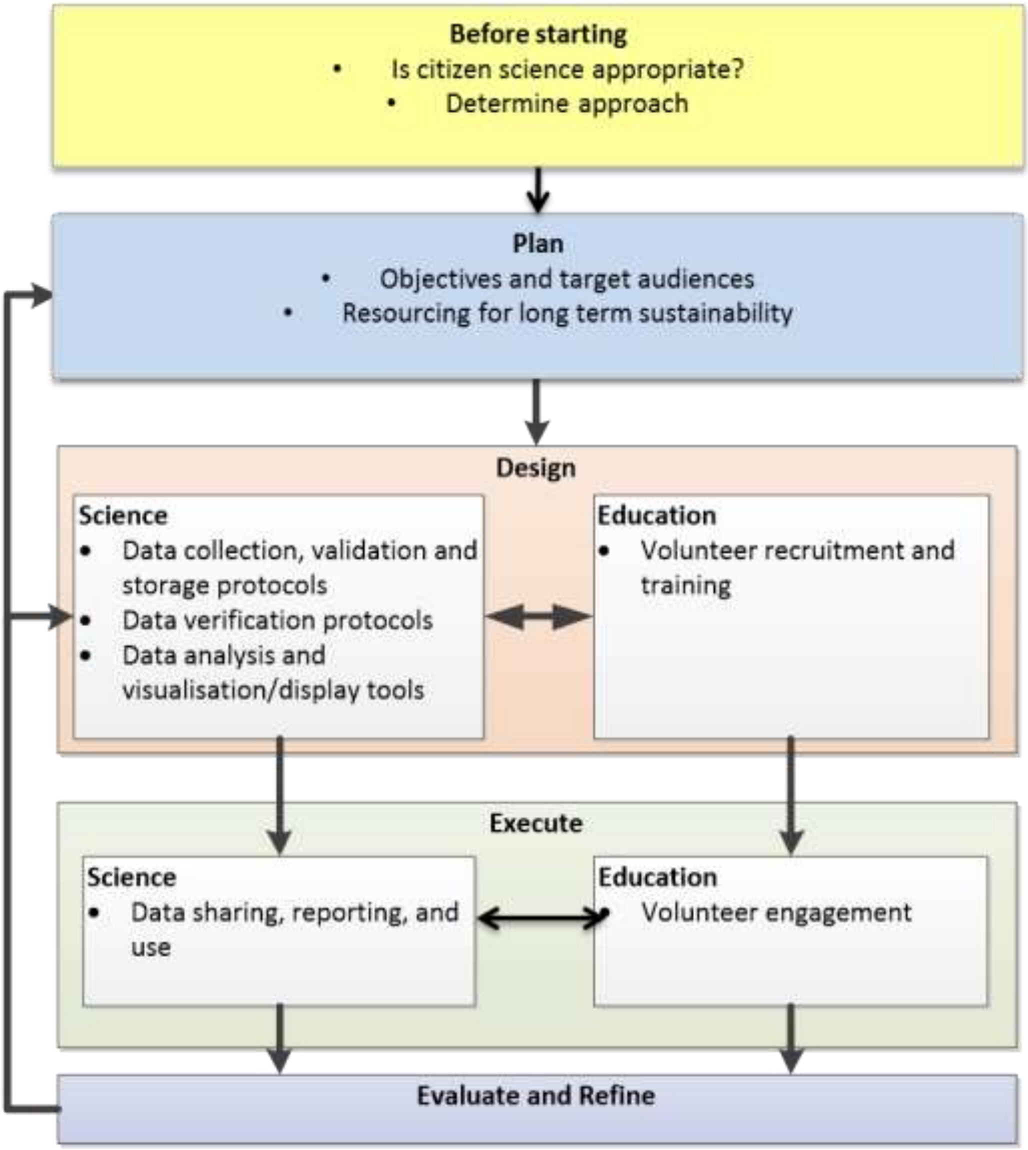
Finally, the collaborative potential of citizen science projects may be stymied by the wariness of scientists to include citizens in meaningful activities (Rotman *et al.* 2012). Haywood & Besley (2014) argue that citizen science has relied on one-way communication models – where information is transmitted from the expert to the non-expert (Haywood and Besley 2014).

Best Practice Framework

To address these challenges, I present a best practice framework for citizen science projects (Figure 4) and describe considerations for each framework element.

To demonstrate how the framework may be used for different types of projects at different stages of their lifecycle, I provide case studies from an existing action / co-created project (Popes Glen Bush Regeneration) and an embryonic investigation project (Science4Wildlife).

Figure 4 – Best practice framework, embedded in the project lifecycle adapted from Roy (2012) and Tweddle et al. (2012).



BEFORE STARTING

Project coordinators must first determine if citizen science is appropriate. Will involving volunteers help answer the research question? Citizen science works better for some types of data gathering and analysis than others, and requires ongoing support and engagement to succeed (Roy et al 2012, Tweddle et al 2012).

1. *Project approach / typology*

Projects must select an approach that best aligns with their research question. This must consider:

- How will scientific data be used?
- What level of scientific rigour is necessary?
- What level of volunteer engagement is desirable / practical?
- How important is raising public awareness / knowledge?

For example, a co-created approach may work best for community-based initiatives such as bush regeneration; whereas a contributory approach may be better for testing a specific research hypothesis.

PLAN

2. *Objectives and target audiences*

The next step is to develop clear objectives. These should consider scientific and educational components – the importance of each will depend on the approach (Figure 5).

Projects must consider different audience types: the general public, volunteers, and the possible end-users of data researchers, policymakers). Again, the importance of each will depend on the project approach. If projects aim to influence decision-makers, they should clearly articulate how data will be used to answer specific research questions, and how they relate to specific polices (Conrad & Hilchey *et al*. 2011; Tulloch *et al*. 2014).

It may be useful to target a specific audience segment for volunteers – although this will impact project design and the type, volume and geographical spread of data that can be gathered (Tweddle et al, 2012)

Figure 5 - Celebrate Urban Birds (CUB)'s project objectives prioritise education and target a specific volunteer segment. CUB is a 'conservation', 'contributory' project (C.L.O., 2014)

> Founded in 2007, Celebrate Urban Birds is a year-round project developed and launched by The Cornell Lab of Ornithology. Its primary purpose is to reach diverse urban audiences who do not already participate in science or scientific investigation.
>
> Another of our goals is to collect high-quality data from participants that will provide us with valuable knowledge of how different environments will influence the location of birds in urban areas.

Existing projects should consider their objectives and audiences as part of their project evaluation. This is particularly useful for initiatives that have developed organically (James 2011).

3. *Resourcing for long term sustainability*

Funding and resource requirements depend on project scope, but are likely to include (James 2011, Tweddle 2012):

- Staff skills and time commitments
- Funding required to develop project infrastructure (e.g. website) and educational materials
- Availability of external funding (e.g. grants, commercial sponsorship)
- Partnerships with learning institutions, government bodies or other organisations. For example, the U.K. Ladybird survey[5] partnered with the BBC, the Centre for Ecology and Hydrology and Angela Ruskin.

[5] See http://www.ladybird-survey.org

DESIGN

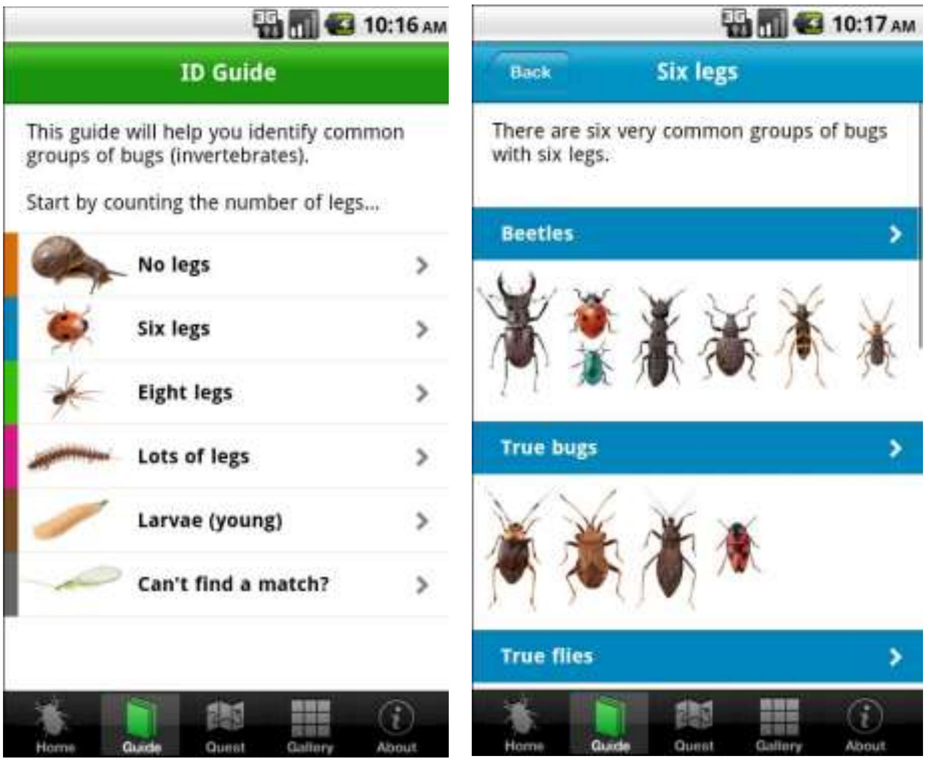
4. Data collection, validation and storage protocols

Data collection protocols should be designed and tested to ensure that projects provide high quality and useful data (Tweddle 2012). The level of scientific rigour will be influenced by the project approach – e.g. an 'investigation' project is likely to need proper sampling design.

Using online forms that include real-time validation can reduce data entry error. For example, eBird's online data entry forms include over 600 geographic and numeric data quality filters to provide instantaneous feedback to users (Dickinson 2012). Potentially dubious records are also flagged for review by a professional scientist or more experienced volunteer (Hochachka 2012).

Volunteer training can also address data validation. For example, The Opal Bugs Identification Project provides a range of training materials to increase volunteer skill, including species identification guides (Figure 7), quizzes and a poster showing where to look for invertebrates in urban settings (Tweddle *et al.* 2012). Distance learning exchanges can be augmented by more personalised interactions delivered through partnerships with local institutions, or the use of regional networks (Davies *et al.* 2011).

Figure 6 – Screen captures from the OPAL bugs identification guide



Projects must also consider how data will be stored, backed-up and archived.

5. Data verification protocols

Verification strategies include (Bonney *et al.* 2009a, Jordan *et al.* 2012b):

- Checking photographs submitted by volunteers
- Field site visits by multiple volunteers to check repeatability
- Checking of data subsets by professional staff

The quality control process used by ClimateWatch – an Australia-wide phenology monitoring scheme – employs species advisors to manually check data for location errors, image errors, duplicate sightings and species misidentification (Ashcroft 2014).

6. Data analysis, display and reporting

Successful citizen science does not end at data collection – data analysis, display and reporting are also critical. Projects should consider (James 2011, Tweddle 2012, Sequeira *et al*. 2014):

- If data needs to be cleaned to remove spurious results
- How data will be visualised, e.g. in the form of maps
- Which statistical analyses methods and tools will be used
- If statistical techniques are required to help with biased sampling
- How results will be reported and presented to different stakeholders, including volunteers, funders and the media.

7. Promotion and volunteer recruitment

To recruit participants, Dickinson *et al.* (2012) recommend working closely with specific target audiences to match project activities with their motivations.

A number of different approaches can be used for project promotion, including media releases, websites, social media, competitions and partnerships with community groups. For example, Operation Spider used a partnership with radio station 891 ABC Adelaide, a poetry competition and a range of educational materials for primary school students (C.L.O. 2010).

EXECUTE

8. Information dissemination and use

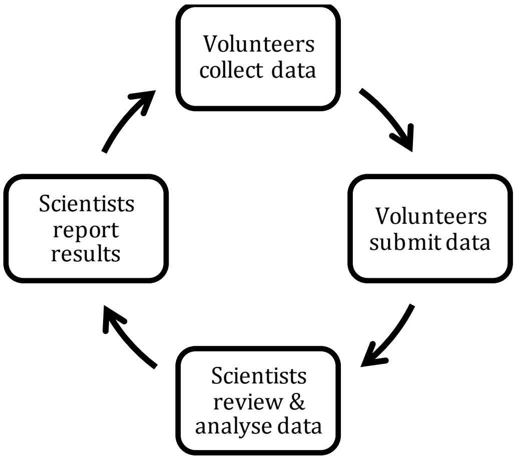
To maximise the use of information in research and policy, it should be shared as widely as possible – with scientists, other volunteer groups, regulatory authorities and academic institutions (Tulloch *et al* 2014). If the goal of the project is to influence academic research policy, appropriate partners should be engaged form the outset to ensure uptake of information.

Data sensitivity and ownership concerns must also be addressed. For example, the CitSci.Org platform includes 'geoprivacy' settings that can mark observations (e.g. of threatened species) as sensitive. These observations appear on the site at low resolution (i.e. with a buffer) and can only be accessed by project owners (Crall *et al* 2013). Data ownership and intellectual property rights are specified in the site's terms and conditions.

9. Volunteer engagement

Successful citizen projects employ a continuous, two-way flow of communication between scientists and volunteers (Figure 7).

Figure 7 – Monarch Larva Monitoring project's communication between volunteers and scientists (Bonney *et.al* 2009)



Volunteers must receive feedback on their contribution as a reward for participation. Many initiatives use spatial maps to illustrate how citizens' contributions are closing gaps in knowledge (Roy 2012).

eBird also appeals to the competitive nature of volunteers by allowing them to create personal bird lists (sorted by date and region) to share online. Allowing volunteers to determine their relative status has led to a rapid growth in participation (Hochachka 2012).

Commonly used communication tools include newsletters, blogs and other social media networks. These should align with the project's target audience. For example, more interactive forms of communication – games and competitions – can be used to engage children (Figure 8).

Figure 8 - Screen capture from the 'Celebrate Urban Birds' "Funky nests in funky places" website (C.L.O. 2013)

Feedback must be collected from volunteers to assess and improve project design (Roy 2012).

Extending volunteer involvement – to include community outreach, data analysis, data visualisation and stakeholder reporting – can increase volunteers' feeling of control and lead to deep, long-term engagement (Bonney *et al*. 2009a, Roy 2012, Sullivan *et al.* 2014).

To translate awareness to behavioural change, projects must connect their research with further actions that volunteers can take towards environmental stewardship (Toomey at el 2013). For example, changes made by 'Birds in Backyards' project contributors include planting more native species and installing birdbaths (BIB 2012).

EVALUATE AND REFINE

10. Project evaluation

Finally, projects must evaluate their impact. Evaluation should occur throughout the project lifecycle and should connect data gathered to the project objectives.

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

The Framework in Action

Case Study 1 : Popes Glen Bushcare Group

Since 1992, a volunteer bushcare group has partnered with the Blue Mountains City Council (BMCC) to rehabilitate a riparian wetland in Popes Glen near Blackheath. Project activities include removal of invasive species, planting of native species and monitoring of stream health and biodiversity.

BEFORE STARTING

1. Project approach

This is an 'action', 'co-created' project – devised and run by volunteers (with support from BMCC).

PLAN

2. Objectives and target audience

When the Popes Glen Bushcare Group (PGBG) was formed in 1992, their goal was to remove infestations of invasive species – primarily gorse, holly and broom. As the group has evolved and achieved many of their short-term goals, their objective has now crystallised as *"Rehabilitate Popes Glen as a pristine native riparian area with public access".*

This is an inspirational and clear objective, though it could be made more specific with the inclusion of a target date. It could also include an educational aspect e.g. "*increase local awareness of the importance of bushland regeneration*".

3. Resourcing for long term sustainability

The group is led by volunteers Alan Lane and Paul Vale and supported by approximately 10 regular volunteers. Alan's science background – including a MSc (Hons) in frog ecology – and grant-writing skills have proven essential to secure funding and provide scientific rigour. Grants from a variety of sources allow PGBG to employ skilled contractors to conduct work beyond the capacity of volunteers[6].

Paul's ability to leverage networks – including the local Conservation Society, Bird Club and Community Alliance – have also enabled the group to play an ever-expanding educational role in the broader community.

This group has a strong partnership with BMCC, who provide grant administration and support, and a Bushcare officer to assist the group on workdays with bush regeneration and safety techniques.

[6] The work program currently being carried out by Popes Glen Bushcare Group with support of the Blue Mountains City Council is funded by a grant from the Environment Trust of the Government of NSW.

DESIGN

4. Data collection, validation and storage protocols

PGBG collects a range of data illustrating quantifiable project impacts (Table 4).

Data are typically collected once or twice a year on paper record sheets. Data are entered into an Excel database that is backed up on multiple hard drives.

PGBG could improve their data accessibility by using an online database for storage, analysis and display.

Table 4 - Data collected by PGBG

Indicator	Data collected	Collection method
Water quality	Temperature, biochemical oxygen demand (B.O.D) dissolved oxygen, phosphate, ammonium nitrogen, nitrate nitrogen	Collected by Alan Lane after extended dry periods (low flow) and rain (high flow). Data is collected on standardised forms and verified by running controls with certified standards where possible.
Biodiversity	Macroinvertabrates	Surveys are carried out by 2 or 3 volunteers using ID charts supplied by Streamwatch/Australian Museum.
	Stygofauna	Samples are taken by Alan from boreholes and enumerated by Dr Grant Hose at Macquarie University.
	Birds	Surveys are take over a one-hour period in a specified area by a qualified professional birding guide (Carol Proberts). Carol records birds visible or audible from the area. Only birds definitely identified are recorded.
Vegetation	Weeds	Vegetation surveys are conducted by Paul Vale in 3 areas: • Braided stream/floodplain interface (transect of 10x40 metres) • Headwall area, taking in all flow lines across the cut (transect of 10x40 metres) • Weedy flat area significantly higher than the creek line (quadrat of 20x20 metres) A standard list of weeds is checked and recorded in each area, along with a separate list of indicative native plants. New species (of both weeds and native plants) are also recorded. Data recording sheets use a standard 7-point cover/abundance scales. Reference books, local vegetation guides and plant experts (including BMCC employees) are consulted to support identification.
	Native vegetation - planted and self generated	

5. Data verification protocols

Data are informally reviewed when entered into the database. To date, these methods have met the project's needs - in terms of demonstrating progress and meeting grant monitoring requirements.

Formalised and clearly documented verification methods may be required for PGBG's data to be published in peer-review journals or used by decision makers.

However, given limited time and resources, more elaborate data verification methods are not currently feasible.

6. Data analysis, display and reporting

PGBG use photo surveys to visualise the impact of their work over time. Posts are used to ensure photos are taken at the same location. Post locations are documented by GPS readings and compass and tape measurements (with detailed written descriptions).

Photo surveys are currently shared with BMCC bushcare officers and program coordinators. PGBG should considering publishing them on their project website.

7. Publicity and volunteer recruitment

PGBG recruits volunteers through letterbox drops, community newsletters, articles in the local paper and the BMCC website.

Unfortunately, volunteer numbers are dropping. PGBG recognise the need to implement new strategies for recruiting volunteers – such as targeting school children[7] and increasing public access and signage. PGBG's long-term goal is to upgrade the Glen's walking track and establish a picnic area – though this is likely to be costly and is not covered by existing grants.

The group's work is included as a case study in environmental management programs at three tertiary education institutions. In 2013, BMCC organised a workshop at the site with Blackheath Primary School teachers and students. This involved brief presentations and practical modules on water quality, water chemistry and macroinvertebrates.

BMCC should establish this as a regular event and expand to other schools.

EXECUTE

8. Information dissemination and use

Results from the project are shared and used in a number of ways:

- Finalised datasets are sent to BMCC
- Specific details required by each grant are sent to the relevant funding body
- Project learnings are shared informally with other bushcare groups e.g. via the inaugural 2013 Bushcare Conference (organised by Paul)
- To alert authorities about pollution issues. For example, in 2009, a report indicating significant sewage contamination of local groundwater was submitted to Sydney Water[8].

At the end of the project's current phase (2018), PGBG will publish a full report for distribution to other bushcare groups, Councils and Government agencies.

PGBG should consider sharing their data more widely - e.g. with Streamwatch for water quality monitoring, the Atlas of Living Australia for biodiversity monitoring – and more frequently on their website.

9. Volunteer engagement

PGBG keep their volunteer network engaged through a monthly newsletter, updates in the regional Bushcare group newsletter and ad-hoc communications sent to stakeholders following significant events.

PGBG should update their website[9] more frequently with existing material e.g. newsletter content, photo surveys

[7] Other local bushcare groups, e.g. the Garguree Swampcare Group, successfully use this approach.
[8] Unfortunately, Sydney Water regarded the data as indicating trivial levels of contamination and took no action.
[9] See http://www.bushcarebluemountains.org.au/groups/popes-glen

and grant reports. They could also use social media tools – such as Facebook and Twitter – to engage with younger audiences. The challenge is that all members are volunteers who are focused on achieving the projects objectives, with limited time to spend on volunteer recruitment and engagement activities.

EVALUATE AND REFINE

10. Project evaluation

PGBG report on progress against objectives at the individual grant level. Each grant includes a detailed monitoring and evaluation plan with specific outcomes.

Feedback on the project is collected from volunteers on an ad-hoc basis e.g. following the Bushcare Conference. This could be formalised on the project's website.

Case Study 2: Science4Wildlife

Science for Wildlife Inc's (S4W) "Blue Mountains Koala Conservation" program aims to help identify high priority areas for koala conservation in the Greater Blue Mountains World Heritage Area (GBMWA). Koalas have recently been spotted in areas of the GBMWA where they have not been seen for many years – further research is required to understand their migration patterns.

Currently, koala sightings are reported to S4W verbally or by email. S4W wants to explore citizen science approaches to extend the reach and accuracy of this approach.

Findings from The Great Koala Count's NSW and SA (Cleary 2014, Sequeria 2014) indicate that citizen science can be a useful tool for koala conservation.

BEFORE STARTING

1. Project approach

Citizen science is one component of S4W's research program – citizen's sightings will be followed up further ecological research[10]. As the focus is on scientific research goals requiring data collection from the physical environment, this can be classified as 'investigation' project.

S4W must consider what level of participant involvement best aligns with their research approach – i.e. if a 'contributory' model will work best, or a 'collaborative' one.

PLAN

2. Objectives and target audiences

This project lends itself to dual monitoring and engagement objectives, e.g.:

- *To identify where koalas are found in the GBMWA (to allow further ecological research)*
- *To raise awareness about koalas within the GBWHA community and engage the community in koala research and conversation.*

Koalas are typically located away from human settlements. To access koala sightings in more remote area, S4W should consider targeting specific volunteer audiences more likely to access these areas e.g. regular bushwalkers, bird-watching groups, landowners and naturalists.

This targeted approach may be supported with a general awareness campaign for the general public.

[10] Other research activities include ground-truthing, habitat mapping, koala tagging, and DNA collection

3. *Resourcing for long term sustainability*

Over the project's expected lifespan, S4W will require staff members to recruit and train volunteers, verify data, produce promotional material and regularly communicate with stakeholders.

S4W should consider how the project will be supported:

- Are external sources of funding required? e.g. Government grants, philanthropic bodies, crowd funding[11]
- Can partnerships with academic institutions, government bodies and local businesses be leveraged?
- Can free tools be used to minimise costs?

DESIGN

4. *Data collection protocols*

S4W should use data collection forms that include enough detail to verify the accuracy of a koala sighting, but are short enough for easy completion.

Based on learnings from the NSW Great Koala Count (Cleary 2014) required observation data are likely to include GPS coordinates; a photo; date and time; type of tree the koala was in; what the koala was doing (eating, sleeping, etc.); property type (private land, national park, etc.), and the volunteer's contact details.

Collection methods could include paper forms, online forms and/or a smart-phone app. S4W should select the method/s that best aligns with their target volunteer audiences' technological capabilities.

Data should be stored on a centralised online database. Initial research in this area identifies a number of potential tools (Table 5).

Training material must also be made available to support the data collection process, such as a user guide available online and as a printable PDF.

5. *Data verification protocols*

Once submitted, sightings should be tagged in the database as "to be verified". S4W staff will then verify the sighting by checking any attached photos and /or contacting the volunteer.

As S4W's volunteer network grows, skilled volunteers could perform verification tasks.

6. *Data analysis, display and reporting*

Data collected from volunteers will be used as input for S4W's additional research and analysis.

Verified sightings should be displayed as an interactive map, available for registered users. To ensure privacy and protect threated species, only S4W staff should be able to access full observation details; published sightings should be buffered (as per CitSci.org's geoprivacy settings).

7. *Promotion and volunteer recruitment*

Promotional activities could target local newspapers and radio stations, as well as leveraging S4W's existing website, newsletter and social media channels. S4W could also consider targeting the many community groups operating in

[11] Crowd funding – e.g. via an online platform such as Pozible – might be feasible, as koalas are a charismatic species likely to raise strong public interest.

the Blue Mountains with a sustainability[12] focus.

As a media hook, S4W could align campaigns with specific dates connected to fauna conservation, e.g. National Threatened Species Day.

EXECUTE

8. Information dissemination and use

A summary level of the map should be publicly available on the S4W website, to illustrate project results and attract new volunteers.

S4W could also consider sharing observation data with other biological recording schemes, such as The Atlas of Living Australia.

9. Volunteer engagement

Volunteers should be kept engaged through ongoing communications, such as newsletters and Facebook updates.

Deeper engagement may also be achieved through occasional face-to-face workshops outlining further steps volunteers may take towards koala conservation.

10. Project evaluation

S4W must also consider how they will evaluate project performance. This must connect to the project goals and approach; and consider how well citizen science data is contributing to answering the research question. For example:

- How many citizens are submitting koala observations?
- How accurate are these observations?
- Are they limited to particular geographic areas?

S4W should also provide a formal mechanism for volunteers to provide feedback e.g. via an online survey. This feedback should be incorporated into the program design and provide a measure of impact on volunteer attitudes and behaviours.

[12] See http://www.sustainablebluemountains.net.au/resources/local-sustainability-groups-and-organisations/

Table 5 – Potential 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

Discussion and conclusions

As illustrated by numerous examples cited in this report, citizen science can be very effective at advancing scientific knowledge. Some projects also demonstrate the ability to achieve educational outcomes and change attitudes and behaviours.

Citizen science projects face a number of challenges that may prevent the realisation of these benefits. These include issues of data integrity, lack of resources and difficulties engaging volunteers.

As illustrated by the case studies, employing a best practice framework for project planning and assessment can be a useful tool to help address these challenges:

- Issues of data integrity can be overcome through robust data collection, verification and analysis procedures
- Educational impacts can be maximised by strategies to increase public awareness and engagement, and ongoing volunteer communication
- Projects must be supported by clear objectives, target audiences, and evaluation methods

Further research and analysis is required to adapt the framework in more detail for each typology. Based on this, detailed criteria should also be developed for each stage of the framework.

Even with excellent planning and assessment tools, projects may still face significant barriers in terms of data utility, scientific acceptance, and funding opportunities. This is a reflection of the field's immaturity and current lack of cohesion.

The proliferation of technology platforms has resulted in volunteer confusion, data inconsistencies and unnecessary competition; isolated systems limit opportunities to collaborate and share data across networks. A unified approach to citizen science requires an industry-standard data collection, storage and dissemination platform. The Atlas of Living Australia's FieldData software is likely to fill this role. Whilst this software offers good functionality and ease of use, it must be enhanced to include a smart phone plugin, and require less technical expertise to set up. Much could be learnt from the excellent Indicia platform in available in Europe.

Projects also require access to supporting resources, including case studies, guidance on best practice, a project register, and a tools register. The creation of the 'Citizen Science Network Australia' in May 2014 (CSNA 2014) is a promising step in this direction. The network should also drive field growth and improvements, e.g. by developing standardised data collection and evaluation frameworks.

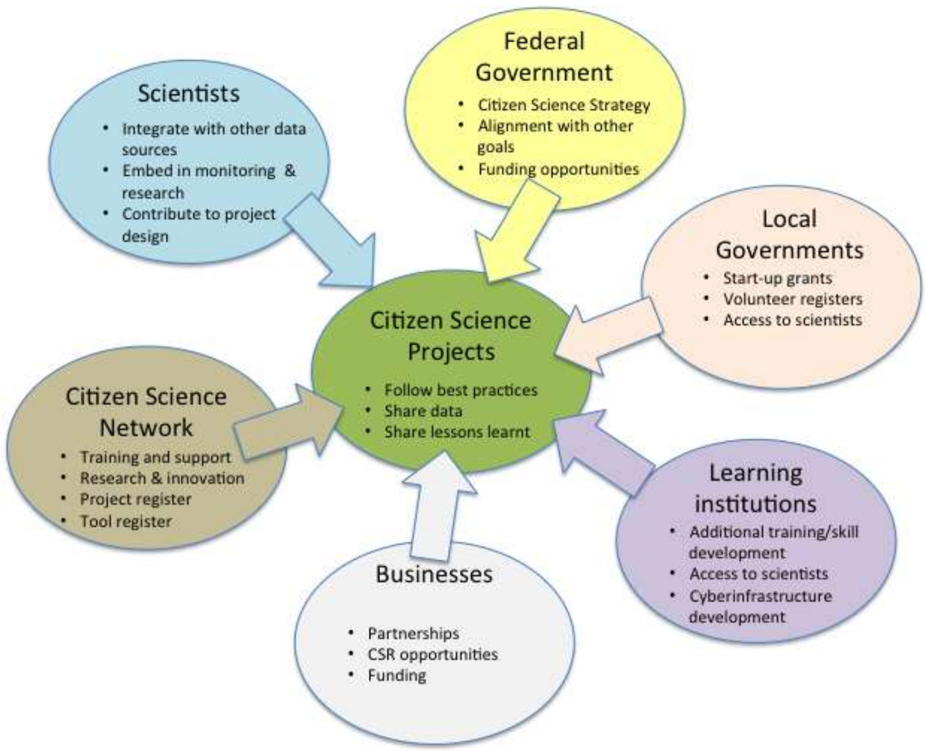
The field would greatly benefit from a national citizen science strategy, as is currently being explored in Europe (E.C. 2014). This would align citizen science efforts with issues of strategic importance and ensure integration with other conservation policies (e.g. Australia's Biodiversity Conservation Strategy). It would also provide targeted funding opportunities. Whilst the current political climate may not be conducive to additional conservation funding, citizen science is a potential win-win approach that can provide high quality and practical benefits, at lower costs than traditional methods.

To remove the stigma associated with volunteer-collected data – and provide evidence for political support – it is critical for scientists to accept citizen science as a legitimate and necessary approach. This includes regularly integrating citizen science data with other data sources; considering how citizen science can be embedded in monitoring and research; and clearly acknowledging datasets that include citizen collected data. However, this cultural shift is unlikely as long as scientists continue to be evaluated on data gathering for the sake of building scientific knowledge alone.

Learning institutions – such as Universities and Museums – may need to lead the way for this change, and provide additional support for the citizen science field. This includes providing access to scientists, developing new training programs to enhance the skills of project coordinators and volunteers, and assisting with the development of open-source GIS and cyberinfrastructure tools. The University of South Australia is already a pioneer in this regard.

Given the pace and intensity of environmental change, additional ecological monitoring is critical for conservation initiatives. Increasing the public's awareness of conservation issues is also critical to trigger social change. The capacity of the citizen science field must be bolstered to help it achieve these aims (Figure 9).

Figure 9 - Capacity building framework for the citizen science field



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