CITIZEN SCIENCE

Opportunities for Community Engagement and Environmental Education

Fungi Foray held in 2016 at Marlee Reserve, Parklands, as part of the Backyard Bandicoots project (a collaboration between City of Mandurah and Murdoch University). Photos show a) background information provided to participants at start of event, b) Dr. Bill Dunstan, fungi expert and researcher from Murdoch University demonstrating how to dig for underground fungi, and c) one of the fruiting bodies collected during this foray, cut open to show the internal morphology. Photos courtesy of Backyard Bandicoots Project.

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Executive Summary

Citizen science refers to the participation by the public in genuine scientific research, and such projects generally involve a partnership between professional scientists/researchers and non-professionals. Citizen science can be implemented across a broad range of disciplines, and is particularly common in ecological and environmental research, where citizen scientists can contribute long-term monitoring data. The ten principles of citizen science have been developed as a guide to best practise to ensure high quality projects that are meaningful for both project developers and participants.

Stand-alone citizen science projects require significant planning and development, and expertise from various disciplines. Important aspects when designing a project include choosing a suitable scientific question, forming the project team, developing, testing and refining protocols, recruiting participants, training participants, accepting, editing and displaying data, analysing and interpreting data, and disseminating results. Careful design of projects is essential to achieve the potential scientific and community benefits of citizen science.

Benefits of citizen science for research/science include advancing scientific knowledge via analysis of data and publication of scientific findings, collection of vast amounts data that would be difficult or impossible to collect otherwise, and access to private land. Benefits for the participant, the community, and society are more challenging to measure, but may include improved scientific literacy, increased topic-specific knowledge, increased connection to the land and appreciation of ecosystems, feelings of ownership and stewardship of the land, and community building. Identifying and evaluating the intended outcomes of participation in citizen science projects is crucial to the on-going success of citizen science as an education and outreach tool. This evaluation requires input from personnel well-versed in qualitative research methodologies.

There are several limitations of citizen science of which project developers and those looking for support projects should be aware. There should be a genuine intention that data collected from citizen science projects is used to advance scientific knowledge. Data quality and the potential for sampling bias are both potential issues that can be overcome or taken into account during project development or data analysis. Participation in citizen science is often biased towards certain demographic groups, which represents a missed opportunity to engage certain groups and to incorporate a diverse range of perspectives and knowledge. Efforts should be made to engage a diverse variety of the public in citizen science projects; how to approach this will depend on identifying the barriers to participation, of which there may be multiple, and which may differ from one project to another.

Partnering with researchers can be beneficial for local government authorities, and some reflections from an employee at the City of Mandurah are provided to demonstrate these benefits. Case studies are provided to showcase two successful citizen science projects that the Shire of Mundaring has supported; and to demonstrate how an LGA can contribute to, and benefit from, citizen science projects without having to make a large investment.

Citizen science can be a very effective tool for engaging the public in science, and has many potential benefits. Careful planning and development of projects, and comprehensive evaluation of outcomes, is crucial to ensure the potential benefits of citizen science for science and society can be realised.

Contents

What is Citizen Science?

The Cambridge English dictionary defines citizen science as “scientific work, for example collecting information, that is done by ordinary people without special qualifications, in order to help the work of scientists” (Cambridge Dictionary, 2020). However, this term has in the past been used to refer to at least two distinct concepts, leading to some confusion about how citizen science is defined. The term was first coined by Alan Irwin (1995) and was used to refer to the “movement to democratize the scientific research process” (Eitzel et al., 2017) which aimed to restore the public’s trust in science, focus scientific efforts on solving complex environmental problems, and make science more accessible to citizens. The second, more broadly used definition - consistent with that adopted by the Cambridge dictionary - refers to the participation by the public in genuine scientific research, and is sometimes referred to as ‘participatory citizen science’ (Bonney, 1996). This is the definition generally adopted in Australia, and the Australian Citizen Science Association’s website defines citizen science as “public participation and collaboration in scientific research with the aim to increase scientific knowledge” (ACSA, 2018b). This is the definition that will be used throughout this paper.

Citizen science projects usually involve a partnership between professional scientists/researchers, and non-professionals. Depending on the level of involvement and contribution made by the public, projects can be categorised as contributory, collaborative, or co-created (Table 1., Bonney et al., 2009a).

Table 1. Citizen science projects can be categorised as contributory, collaborative, or co-created, depending on the level of participation by the public (adapted from Bonney et al. 2009a).

Category	Description	Level of participation by the public
Contributory	designed by scientists, public contribute data	lowest
Collaborative	designed by scientists, public contribute data but may also contribute to project design, data analysis, or dissemination of results	higher
Co-created	co-designed by scientists and members of the public, some members of the public are actively involved in most steps	highest

Citizen science can be applied in a variety of scientific disciplines and there is a lot of flexibility and variation in terms of the scope of projects (see Bonney et al., 2009b, Dickinson et al., 2010, and Roetman and Daniels, 2011 for examples of specific citizen science projects). The level of participation by the public, and how projects are managed can also differ depending on the project. However, there are certain key principles that the citizen-science community (both nationally and internationally) have developed to guide best practise in citizen science projects, known as the 10 principles of citizen science (Robinson et al., 2018, Box 1.). These principles are designed to ensure projects are successful and meaningful for both participants and project leaders.

Box 1. The 10 Principles of Citizen Science (Australian version*)

1. Projects actively involve citizens in scientific endeavour that generates new knowledge or understanding
2. Projects have a genuine scientific outcome.
3. Citizen science provides benefits to both science and society.
4. Citizen scientists can participate in various aspects of the scientific process (such as developing research questions, designing methods, collecting and analysing data, communicating results).
5. Citizen scientists receive feedback from the project.
6. Citizen science has limitations and biases that should be considered and controlled for.
7. Where possible, project data and meta-data are made publicly available and results published in an open access format.
8. Citizen scientists are acknowledged by projects.
9. Citizen science offers a range of benefits and outcomes that should be acknowledged and considered in project evaluation.
10. The leaders of citizen science projects take into consideration legal and ethical considerations of the project.

**based on the 10 Principles published by the Australian Citizen Science Association (ACSA, 2018a)*

Key Aspects of Project Design

Although non-professionals have been contributing data to scientific studies for centuries (Miller-Rushing et al., 2012), The Cornell Laboratory of Ornithology is attributed with defining what we now call citizen science (Bonney, 1996), and has been involved in this form of 'participatory' citizen science for decades. These researchers have published a model for designing successful citizen science projects, which covers key aspects of project design and is summarised below (from Bonney et al., 2009b).

1) Choose the question

Citizen science is well suited to projects such as monitoring studies, where there is need to gather data over a long time period and/or a large geographic scale. Data collection should rely on basic skills, unless the developers have the capacity to offer significant amounts of training and support for participants. Complicated projects tend to attract fewer participants, so if the aim is the reach large numbers of people, questions that can be answered via simple projects are desirable.

2) Form the team

To develop a successful citizen science project requires input from a multi-disciplinary team, including a researcher, an educator, an information scientist/computational statistician, and an evaluator.

3) Develop, test, and refine protocols, forms and supporting information

It is crucial to ensure the public can contribute quality data. Pilot-testing protocols is very helpful to ensure protocols are not confusing or overly complicated. A good data form will mirror the protocol/s, and be simple and logical. Supporting information may include ID guides, videos, podcasts, FAQs and other materials relating to making observations and/or filling in the data form.

4) Recruit participants

To recruit from the general public, a variety of methods can be used, including press releases, direct mailings, newspaper articles, fliers, presentations, and advertising on social media. Local community groups or government organisations can be particularly useful in helping to publicise a project to their members. Deliberately partnering with specific groups (such as schools) from the beginning can be beneficial in designing a project that meets the objectives of the project developers and the participants (e.g. to fit the curriculum or mesh with existing programs).

5) Train participants

The level of training required will depend on the nature of the project and who is contributing, but project developers should ensure they have the capacity to provide the required training to ensure participants are confident in their ability to collect and submit data. Hosting and/or assisting with training workshops is one way that organisations that don't have the capacity to develop their own projects can contribute to the success of an existing project.

6) Accept, edit, and display data

All data must be accepted, edited, and be made available for analysis (by scientists and the general public). Utilising existing data submission and compilation tools (e.g. BioCollect - Atlas of Living Australia, eMammal, eBird) can be useful for organisations that do not have the capacity or expertise to develop their own data display software. Allowing the public to access and analyse data is a valuable way of involving them in the scientific process.

7) Analyse and interpret data

Citizen science often produces datasets that can present some challenges concerning statistical analysis and interpretation. Criteria can be developed to identify and flag erroneous data, so that it can be checked and/or removed prior to analysis. Project developers should be aware of potential sources of error and bias and preferably control for these during data collection (or take into account during analysis).

8) Share results

Results can be published in scientific journals, technical reports, through project websites, and through newspapers, magazines, and newsletters. Dissemination of results is important to make the science widely available, and may also motivate others to join citizen science projects.

9) Measure outcomes

Outputs and outcomes of projects should be measured to determine whether scientific and/or educational objectives have been met. Evaluation of projects is an important step and can help ensure the success of future projects, by learning what works and what doesn't.

Benefits and Outcomes of Citizen Science

Engaging and involving the public in scientific research has many potential benefits (Bonney et al., 2009a), including advancing scientific knowledge (Bonney et al., 2009b, Roetman and

Daniels, 2011), education and knowledge transfer (Roetman and Daniels, 2011, Branchini et al., 2015), increasing community engagement (Roetman and Daniels, 2011), and improving scientific literacy (Trumbull et al., 2000) and public attitude towards science (Miller-Rushing et al., 2012, Aristedou and Herodotou, 2020). Although robust scientific data collection is generally the initial or primary objective, the potential of citizen science projects for contributing to community engagement and environmental education, and fostering Earth stewardship is considerable.

Benefits for science

Bonney et al. (2009b, page 977) state that "Citizen science projects have been remarkably successful in advancing scientific knowledge". Several examples of specific research outputs from citizen science projects can be found in Roetman and Daniels (2011, Table 2, page 251). With regard to ecological research, citizen science allows the collection of vast amounts of data from broad geographic areas, and/or over long periods of time (Roetman and Daniels, 2011), and it has been suggested that citizen science may be the only practical way to gather such data required to address ecological questions at large scales (Dickinson et al., 2010). Another benefit of citizen science for ecological research is the access to private land that otherwise would not be accessible to researchers (Dickinson et al., 2010, Roetman and Daniels, 2011). On-going, large-scale monitoring that is typical of ecological citizen science projects has proven useful in detecting changes in species distribution due to climate change (Cooper et al., 2012), and may provide data to address unanticipated threats to biodiversity (Dickinson et al., 2010). Long-term citizen science monitoring projects can often have unexpected benefits for science, in addition to intended objectives, as researchers can "re-purpose long term data to address a myriad of questions" (Cooper et al., 2012, page 102).

Benefits for participants, the community, and society

Members of the public who participate in citizen science are likely to experience personal benefits such as feeling as though they are contributing to something meaningful, a positive and enjoyable experience, and the opportunity to learn new skills and knowledge from experts in the field.

While it is relatively easy to evaluate whether a citizen science project has made a positive contribution to scientific knowledge, or whether participants enjoyed being involved, it can be very challenging to measure the sociological outcomes of participation in citizen science, such as changes in individuals' attitudes towards science or the environment (Philips et al., 2012). Generally, these types of outcomes are measured via surveys pre- and post-participation, in-depth interviews of participants, or evidence gathered via unsolicited feedback given by participants during the program (Bonney et al., 2009b).

Interviews with participants of the Neighbourhood Nestwatch program revealed that participants developed an increased "awareness and appreciation of the value of backyards as habitat for birds…" (Evans et al., 2005, page 593). In many cases this change in awareness and appreciation translated into behavioural change; with people undertaking activities to preserve or improve the habitat on their property (Evans et al., 2005). Another interview based study found that participation in community-based forestry monitoring projects in the USA led to several benefits regarding knowledge and awareness of ecosystems and ecological processes, and served to reconnect people to the land and foster trust between community, environmental groups, and government agencies (Fernandez-Gimenez et al., 2008, Box 2.).

Box 2. Benefits and Outcomes for the participant, the community, and society

Interviews with participants showed that participation in community-based forestry monitoring projects in the USA led to the following outcomes:

1) Increased knowledge and appreciation of the complexity of ecosystems, increased awareness of how difficult it can be to study ecosystems.
2) Changes in assumptions or preconceived ideas about ecological processes, via social learning.
3) Community building, reconnecting people with the land, and empowering participants to be stewards of the land.
4) Increased trust or credibility between community members, environmental organisations and government agencies.

From Fernandez-Gimenez et al. (2008)

To ensure sound conclusions regarding social outcomes of citizen science, such as changes in education, community engagement, or attitudes or values of participants, it is important that social researchers who are well-versed in qualitative research methods are involved in identifying and evaluating these outcomes. There is a strong push from the academic community for improved evaluation of citizen science projects at the level of the individual participant, the program overall, and the wider community (e.g. Conrad and Hilchey, 2011, Jordan et al., 2012, Philips et al., 2012).

Citizen science projects can differ in terms of the level of participation by the public. Intuitively, it is likely that the opportunities for learning and thus the benefits of citizen science will be increased if participants are involved in multiple aspects of the project and the scientific process. Mitchell et al. (2017) provide some evidence for this, based on evaluation of participation by tertiary students in the *ClimateWatch* citizen science program in Australia. In this study, tertiary students participated in both data collection and data analysis, which lead to an increase in environmental engagement in these students, but importantly, also changed their perception of data used for citizen science. Before participating, 79% of students thought that data contributed to citizen science projects was reliable. After first-hand experience analysing data contributed to this project, only 31% of students agreed that such data were reliable, most likely because they had found erroneous records during their data analysis (Mitchell et al., 2017). This first-hand experience of unreliable records had a positive consequence; students reported taking more care to avoid errors in their own contributions. If this pattern holds for other citizen scientists, it is likely that involving participants in data analysis, not just data submission, will improve their understanding of data reliability and thus improve the quality of their own contributions to citizen science projects. If participants are only involved in contributing data and do not see the “behind the scenes” aspects such as data analysis, they may not have as many opportunities for learning and development.

Limitations of Citizen Science

Citizen science projects present several limitations and challenges that both project developers and those seeking to contribute to projects should be aware of. A selection of common limitations is summarised below, and more information can be found in Dickinson et al. (2010).

Citizen science projects should contribute to genuine scientific research

To be considered a genuine citizen science project, there should be an intention that the data collected is analysed and published as legitimate scientific research (Robinson et al., 2018). This means that for organisations such as local government, it is necessary to partner with a university or institution or organisation engaged in scientific research in order to ensure there is a genuine intention to use the data to advance scientific knowledge. Although participation in citizen science projects has the potential to increase community engagement with science and conservation, and may contribute to environmental education efforts, it should be ensured that the projects that the public are taking part in do contribute to genuine scientific research, as opposed to projects being designed with environmental education as the aim, with no real intention to use the results to advance scientific knowledge. In the latter case, these projects would cease to be formal citizen science and would be more accurately considered outreach or education projects (Robinson et al., 2018).

It is likely that the opportunity to participate in genuine, meaningful scientific research is what motivates many citizen scientists to contribute (Evans et al., 2005), and care must be taken to retain the *science* in citizen science.

Citizen science projects require significant input to be successful

A successful citizen science project requires a reasonable level of input from a variety of different disciplines/specialists (see 'Key Aspects of Project Design', and Bonney et al., 2009b), which can make it difficult for smaller organisations to design and implement their own projects. However, online tools such as BioCollect (a data collection tool available through the Atlas of Living Australia) provide some of the more complex, technical requirements relating to database infrastructure and the technology required to receive and archive data submissions. In addition, organisations without the capacity to run their own projects can contribute to the success of existing projects, for example by helping to recruit participants or by assisting with training workshops or information sessions (see Case Studies for more information).

Data Quality

A common concern about citizen science projects is whether members of the public have the skills and knowledge to contribute good quality data (Dickinson et al., 2010, Kosmala et al., 2016); for example, can they correctly identify the species of interest? It is important for training to be provided to allow participants to build the skills and knowledge required to collect and submit good quality data. There are several approaches that can be utilised to increase data accuracy and account for bias, such as iterative project development (using pilot studies or beta testing to ensure a protocol can be successfully performed before the project is launched), training and testing of participants, validation of data by experts, and replication of data collection by multiple participants (Kosmala et al., 2016).

Volunteers may be reluctant to take part in citizen science if they think the data are not going to be reliable or that the data will not be used. Clear communication about how the reliability of data will be ensured, offering training sessions, and providing feedback and communication about how data will be used are all important in showing participants that they will be submitting valuable data and that their time and contributions are valuable. From this perspective, it would be sensible for local governments to partner with organisations that have experience conducting citizen science projects and can demonstrate that they have tools and methods in place to ensure reliable data collection.

Sampling Bias

To ensure equal sampling effort in ecological studies, professional researchers follow strict protocols, to make sure the amount of time and effort spent looking for organisms is consistent from one study site (or moment in time) to another. The use of rigid or complicated protocols can limit the number of participants willing to contribute to a citizen science project, but a lack of standardisation of survey effort across participants can make it very difficult to tell whether data reflect true biological patterns, or simply reflect differences in sampling effort (Dickinson et al., 2010). Therefore it is crucial for project developers to be aware of the potential for sampling bias, and preferably to design protocols and recruit participants in a way that reduces or eliminates this bias.

A common pitfall of ecological citizen science projects is the tendency for the public to only submit 'positive' results, such as the sighting of a species of interest, and to assume that 'negative' results, such as a nil sighting, are not helpful. However, for most ecological projects it is just as important to gather data on where a species was absent as well as where it was present. This important aspect of study design may not be clear to members of the public who do not have a background in the scientific method or scientific thinking, and so it is important to design promotional and educational material to ensure that prospective citizen scientists understand the value of 'negative' results.

Participation can be biased

Participation in citizen science is often biased towards certain demographic groups and there remains a significant opportunity to engage a more diverse group of participants to better reflect wider society (Robinson et al., 2018). Often, citizen science will fail to engage groups who are historically underrepresented in science, such as certain minority groups and those from lower socioeconomic groups, meaning that these groups do not experience the potential benefits of citizen science (Pandya, 2012). The lack of diversity among participants of citizen science projects also means the projects suffer from a lack of diverse perspectives and knowledge.

Pandya (2012, and references therein) discusses possible reasons for the lack of participation by certain groups. Possible barriers to participation may include the following; people who live in urban areas may have less access to natural areas and feel less comfortable in those areas, people with less formal education may have a lack of familiarity with the scientific process, people who are juggling multiple jobs, have family commitments, or have limited transportation options may find it more of a challenge to balance participation in citizen science with other priorities in their lives.

Box 3. A general framework for encouraging broad participation in citizen science

1) Align projects with community priorities
2) Plan for the project to be co-managed
3) Engage the community at each step
4) Incorporate and value multiple types of knowledge
5) Disseminate results widely

From Pandya (2012)

Another compelling possibility is that people are not motivated to participate because they do not feel that science in general, or a particular scientific question, is relevant to the priorities or values of their community (Pandya, 2012). Pandya (2012) provides a general framework to help scientists build citizen science projects in partnership with communities (summarised in Box 3) but points

out that specific recommendations will depend on the type of barriers that exist in a particular community, and so there is no 'one size fits all' approach to broadening participation.

Offering multiple ways to participate – which may include developing research questions, administration, data entry, data collection, data analysis, dissemination of results, etc. – may help attract a more diverse group of participants. For example, involving the public in developing a research question may be a powerful way to engage those who do not feel that science is relevant to their community values; if people are directly involved in deciding what will be studied, they are more likely to feel that the project is of value and will benefit the community.

Encouraging people to be involved in aspects such as administration, data analysis, or dissemination of results might mean that people who do not feel comfortable or confident collecting data can still contribute to the project based on their own strengths or experience. Targeted recruitment may also help citizen science projects reach a wider audience; for example, limited participation by young people has led to calls to recruit university students as citizen scientists (Mitchell et al., 2017). Partnering with existing community organisations may provide a way to introduce scientific activities to groups of people who might otherwise find their lack of experience with science a hurdle (Pandya, 2012).

Benefits of partnering with researchers; reflections from a Local Government Employee

The City of Mandurah has a long-standing partnership with researchers from Murdoch University, which is of great benefit to both parties. The partnership allows the City to benefit from expert knowledge and targeted research to tackle local environmental problems (e.g. local decline of tuart trees) and provides the researchers with additional funding, as well as support to access study sites, and recruit local residents as participants and volunteers. Although not all aspects of this partnership are strictly 'citizen science' (as defined above), the benefits summarised here are likely to be of interest and relevance to other local government authorities and complement the other ideas presented in this paper.

Through the CoM and Murdoch university partnership, residents have the opportunity to be involved in research in several ways which differ in their level of involvement but all provide residents with the opportunity to learn directly from experts in the field. For example, in 2016 and 2017, as part of the Backyard Bandicoots program, volunteer 'citizen scientists' were recruited for 'Fungi Forays'. Participants were provided with some background information and in-the-field training on how to collect the fruiting bodies of underground fungi, which make up a large proportion of the diet of the local bandicoot, the quenda (*Isoodon fusciventer*). All samples that were collected during fungi forays were donated to Murdoch University researchers, where samples were identified and catalogued, and some samples were used in an experimental research project which is currently being prepared for publication.

Some residents were involved in a separate research project in which they offered their gardens as study sites, completed an interview about their perceptions and interactions with wildlife, and in return received information concerning the types of animals that visit and use their garden (based on images from remote sensor cameras placed in their garden). The researchers benefitted from being able to access private land as study sites, and were able to collect data for a scientific study regarding the association between particular garden characteristics and frequency of quenda visitation. This research project is currently being prepared for publication. Residents were also exposed to the research projects at community

events or at public presentations where researchers talked about the projects and answered questions from the public.

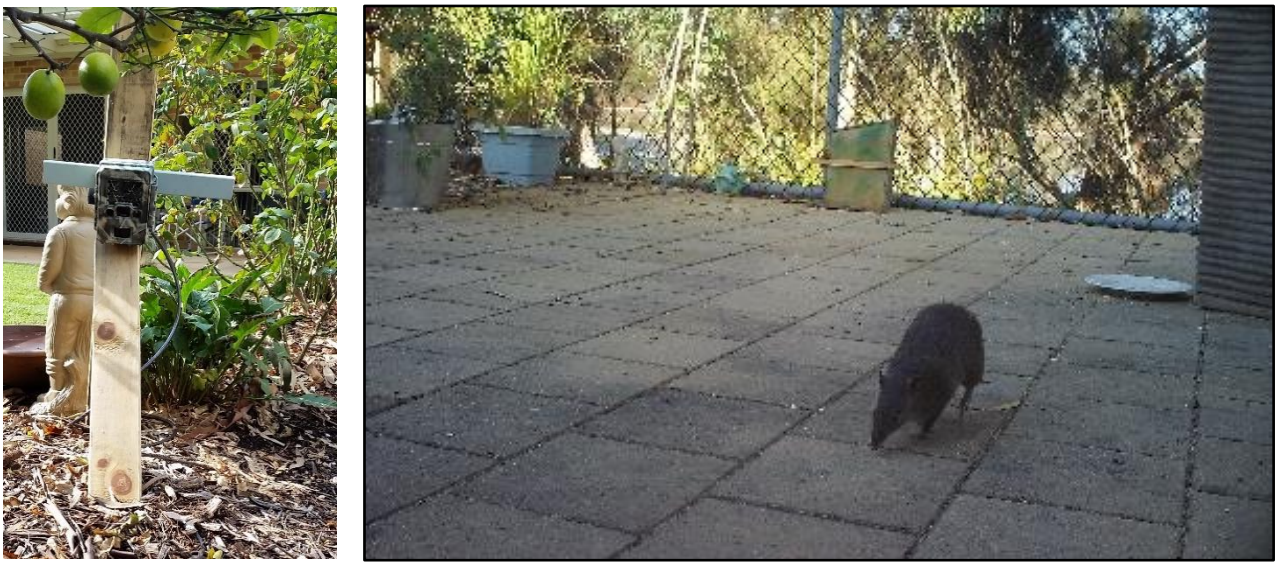

Figure 1. Photos from the Backyard Bandicoots Garden Project. Photo (a) shows a remote sensor camera set up in a garden, and (b) shows a remote sensor image of quenda visiting a garden. Photos courtesy of A. Kristancic.

All levels of resident-participation made possible due to this partnership provided residents with the opportunity to learn directly from experts in the field, and allowed for conservation messages and scientific information to be delivered to residents by the researchers. Bonnie Beal-Richardson, Senior Environmental Education Officer from The City of Mandurah, believes that residents are more likely to take such messages on board when they are delivered by researchers who are not only an authority on the subject thanks to their academic standing, but also represent a 'neutral party'. As Bonnie says, "It would be hard to be open to a message about conservation from a local government one day if you've been fined by them the day before".

With regard to citizen science, Bonnie offered the following reflections;

"I think citizen science helps people become curious about the same questions that researchers are asking… by inviting them to step into a different value and view the world from this, albeit temporarily, citizen science opens people up to a whole new way of learning, behaving, and thinking, and they are therefore being influenced on a deeper level"

"… people also learnt a lot by doing – whether that be fungi forays or hosting cameras in their backyards. Again, this opens them up to another way of learning that they perhaps don't always access. They're also more emotionally invested when it's something they too are doing, and not just someone else telling them things they've learned. Citizen science gives people a chance to calculate and see the results for themselves, which ultimately becomes a much more powerful motivator of change for them."

Case Study 1 – Farm Dams Project (EMRC/Murdoch University)

Background and Context

The 'Farm Dams as refuges for freshwater plants and animals in a drying climate' project (hereafter referred to as the 'Farm Dams project') was a collaboration between the Eastern Metropolitan Regional Council (EMRC) and Murdoch University, and provides an example of a research project incorporating citizen science to benefit both science, by increasing the amount of ecological data collected, and the community, by engaging and involving the public in the scientific process. The project took place across private land (>50 farm dams) and government reserves (>50 natural waterbodies) in the Shire of Mundaring, and Cities of Swan and Kalamunda. Data were collected in Spring 2018 and Autumn 2019.

The scientific aims of this research project were to determine 1) the native freshwater biodiversity supported by farm dams, and 2) whether paddock (isolated) and on-channel dams support different components of native freshwater biodiversity, 3) identify which characteristics of farm dams are associated with high numbers of native species (Robson and Chester, 2019). In addition, there was a fourth aim; "to train landholders as citizen scientists and increase the capacity of all landholders with farm dams to manage them to sustain native biodiversity through web-based knowledge dissemination".

Figure 2. Examples of local aquatic biodiversity that may benefit from habitat provided by farm dams (a) a frog (b) a dragonfly, and (c) a white-faced heron (photos courtesy of Graeme Worth).

Contributions and Design of Project

This project was a collaboration between the EMRC and Murdoch University to investigate the function of dams as habitat in a drying climate. It was supported with funding from a Lotterywest grant that was developed and submitted by the EMRC, incorporating intellectual property attributed to Murdoch University. The EMRC were responsible for contract administration and project management, and for the majority of the community engagement efforts for the project. Both Murdoch University and the EMRC contributed significant cash and in-kind contributions to the project.

Professional researchers from Murdoch University were responsible for study design, collection of aquatic plant, invertebrate and tadpole biodiversity data, and collection of water quality and habitat data. Citizen scientists collected and submitted data about water birds and frogs that were using dams during Spring 2018 and Autumn 2019, in order to complement the biodiversity data collected by researchers.

Landowners and other volunteers were recruited as citizen scientists, and were trained in how to identify bird and frog species that may inhabit farm dams, and how to collect these data using FrogID (Australian Museum) and Birdata (BirdLife Australia) apps. Utilising these

apps for data collection provided a user-friendly and reliable way to collect sighting information. For example, frog calls can be recorded and submitted using the FrogID app. Citizen scientists who make the recordings can access resources to aid them in identifying the frog via the call, and in addition, recordings are then validated by experts at the Australian Museum, improving the quality and reliability of the identifications. The Birdata app provides information such as a list of local species (with photographs) to aid people in identifying birds they have seen, and also allows users to record behaviours observed (such as feeding, nesting, breeding, etc). In the context of this project, the latter provides valuable additional information concerning how birds are using dams.

The Murdoch University researchers downloaded the data submitted by citizen scientists and were responsible for data analysis and compilation of results.

Role of Local Government Authority (LGA)

Staff from the Shire of Mundaring assisted EMRC personnel to identify, via the Shire's GIS systems, local properties that had dams. EMRC staff prepared an invitation letter that was sent to these property owners on Shire of Mundaring letterhead. Therefore, the initial invitation came from the Shire, as it was thought that an approach to residents from a more familiar organisation might encourage greater participation. The Shire also provided in-kind support by providing a venue to host a workshop for landholders.

These types of assistance from local governments are very valuable and should be encouraged; they do not require a large investment from the LGA, but have a huge potential to increase local participation, and therefore enhance environmental education and engagement with science in the local community. For example, residents are likely to be more receptive to the initial invitation to participate if it comes from a known organisation and if the training/information sessions are at a local venue that they are also familiar with.

Benefits of the Project

The Farm Dams project has so far been highly successful, and has delivered on all of the Stage 1 Aims (see Background/Context). As well as having provided scientific outcomes and improved scientific knowledge, the project has led to increased community engagement, and the results will inform and guide future management actions.

Scientific Knowledge

This project has delivered on the three main scientific aims (Robson and Chester, 2019).

Aim 1: "To determine what native freshwater biodiversity is supported by farm dams"

It was found that, overall, farm dams support substantial freshwater biodiversity (including invertebrates, plants, frogs and birds), and that farm dams are the main aquatic habitat available in summer, when most natural waterbodies are dry. This confirms the potential of farm dams as refuges in a drying climate. However, analysis showed that while each dam supports native biodiversity, no one dam supported all the species recorded. Therefore, to support the full complement of biodiversity in the region studied, multiple dams across the landscape are required.

Aim 2: "To determine whether there are differences between paddock and on-channel dams, due to different degrees of connectivity"

It was found that Gambusia (introduced mosquito fish) were more likely to be present in on-channel dams, presumably due to their connectivity to streams. The presence of this exotic

species appears to have a negative effect on the diversity of native freshwater invertebrates, with on-channel dams having less invertebrate species than the more isolated paddock dams. Given the differences in the biodiversity supported by each type of dam, different management approaches will be better suited to each type of dam.

Aim 3: “to identify characteristics of farm dams associated with higher native biodiversity”

Results indicated that dams containing submerged aquatic plants or woody debris and leaf litter had increased animal diversity, as they provide food and/or shelter from predators, while dams without Gambusia had increased diversity of other animals. These findings will guide recommendations for management to increase biodiversity (see Benefits for land/water management section below).

Engaging with landowners also had several benefits for future research. The power of engaging landholders and local residents in projects regarding the local environment is that they are very familiar with the local area (particularly their own property) and often have valuable insights that researchers who are not familiar with the area may not be aware of. For example, many landholders reported that they have observed differences from year to year in terms of the biodiversity supported by their dams. These landowners therefore suggested that a larger dataset is required, to capture this variability. Landholders also suggested novel methods for control of Gambusia, some of which would be viable options and will be trialled if further funding is secured.

Benefits for participants and the wider community

Through participation in this project, citizen scientists had the opportunity to learn new skills, specifically with regard to identification of frogs and waterbirds. Participants were also able to learn about the water quality and biodiversity of their own dams, how their dam helps support native biodiversity, how their dam compares to others in the area, and whether land management activities that they are undertaking are having the desired effect on biodiversity and water quality.

Through surveys, participants reported strong satisfaction and engagement with the project, and were excited about the potential to manage their dams to enhance local biodiversity. All participants surveyed said they would like to be involved in stage 2 of the project, and that their knowledge about freshwater aquatic biodiversity of farm dams had increased since participating in the project. Testimonials from participants showed that people who took part in the project enjoyed finding out about the aquatic biodiversity of their site and the region in general, welcomed the opportunity to learn scientific information from experts from Murdoch University, and enjoyed being part of a project that would have a positive impact on the local environment.

One tangible benefit for the wider community was the development of a waterbird guide for the Perth Hills (developed in conjunction with BirdLife WA), which is now available for general use by the community.

Benefits for land/water management

Results about which characteristics of farm dams are associated with higher biodiversity will be used to inform management actions to improve biodiversity associated with dams. These are as follows (taken from Robson and Chester, 2019):

1) in dams without aquatic plants, increasing plant cover should increase animal diversity

2) in dams without woody debris and leaf litter, increasing cover should increase animal and plant diversity

3) in dams with Gambusia, reducing Gambusia numbers should increase animal diversity.

Due to the high level of engagement with the community achieved in this project, landholders are enthusiastic about the potential to increase biodiversity in their own dams, and keen to trial the management actions identified. It is likely that landholders would be less inclined to offer their time and their property for trials of management actions if they had not been actively involved in the processes leading to the identification of management actions.

Case Study 2 – Aussie Backyard Bird Count (BirdLife Australia)

Background and Context

The Aussie Backyard Bird Count (ABBC) is one of the largest citizen science projects in Australia, with 88 270 people participating across Australia in 2019, submitting a total of 105 888 counts. The purpose of the count is to help BirdLife Australia develop and understanding of local birds, while giving the participant a chance to get to know the wildlife that lives nearby (BirdLife Australia, 2020b). The project has run every year since 2014, during National Bird Week, and focuses on identifying broad trends in the distribution and abundance of bird species across Australia.

Figure 3. 'Aussie Backyard Bird Count' 2020 promotional image, courtesy of BirdLife Australia.

Contributions and Design of Project

The ABBC was developed by scientists and staff at BirdLife Australia, a not-for-profit organisation dedicated to the conservation of Australia's birds. BirdLife Australia are responsible for running the project, including developing the protocols, providing information and support to participants, providing data submission software, accepting, vetting, displaying and analysing data, and generating and disseminating results. The general public (the citizen scientists) are responsible for submitting checklists detailing how many birds and which bird species were seen in a 20 minute timed observation period. Participants can count birds in whatever location they choose, which is often their own

backyard/garden, and can submit as many 20-minute checklists as they like during the project, which runs for one week each year. The vast amount of information and online support provided for this project, the user-friendly interface for data submission, and the clear communication regarding how data are vetted and used are all likely to be important factors contributing to the success of the ABBC each year. Further details of these aspects of the project are provided below.

Information and Support

The ABBC website contains up to date information for the current year, and a detailed Frequently Asked Questions section that gives a lot of information about various aspects of the project (BirdLife Australia, 2020b).

The 'Bird Identification' section provides information on how to follow the specific protocol for this project; including what to do if you are unsure of the identification, which birds to count, and what to do if you don't see any birds.

The 'About the Count' section gives background information about the purpose and history of the project, basic information on how to participate, and useful information regarding how data are vetted to ensure reliability, and how data will be used.

The 'How to Count' section provides information about how data can be submitted, how to download the app, who can take part and whether specialised equipment is needed, how often counts can be submitted, and plenty of details about why data are collected in a certain way and how to ensure you stick to the protocol.

There is also an FAQ section to provide 'Help with the website and app', which gives technical support to help participants download and use the app, to troubleshoot issues with the website and/or app, and to help users fix any mistakes before submitting their counts.

Each FAQ section also provides a link to a 'contact page' to allow participants to access specific support if the FAQs do not answer their question.

Data submission software

Data can be submitted via the ABBC app or website (https://aussiebirdcount.org.au/). The app provides a user-friendly interface for submitting counts, including an on-screen timer to count down 20 minutes, and a drop down list of suggested species is provided once the user starts to enter a name of a bird. Participants can also use the built-in "Bird Finder", in which users can specify the size, shape, and/or colours of the bird observed. Users are then provided with a list of potential species including photographs, a distribution map and a written description of each species. This can be a quick method of determining the correct identification of an unknown bird. Via the website, BirdLife Australia also provides links and suggestions for other resources to help participants improve their bird identification skills. Counts can also be submitted via the website for those who prefer this method, and similar user-friendly resources exist for helping participants to identify birds, such as a drop down list of bird species names and a link to the web version of the "Bird Finder".

These features, on both the app and website, make it simple for participants to submit counts, which is likely to contribute to the success of this project and the large – and growing – number of people who take part each year.

Accepting, displaying and vetting data

Via both the app and website, participants can access 'Live Statistics' in order to see a running tally of how many checklists have been submitted, how many species and how many individuals have been seen. These summary data can be viewed for Australia as a whole, for specific locations, and for the participants own data. There is also an interactive map showing the location of checklists, and a species list for each location, which allows users to explore what species of birds were seen in specific locations.

All data received are vetted for accuracy by expert ornithologists from BirdLife Australia (BirdLife Australia, 2020b). These experts examine data from locations that they are very familiar with, and they are able to remove any IDs that are obviously wrong, for example if the proposed species does not live in the geographic area from where the data were collected. The organisation also receives emails from people who realise they have made a mistake, and these are manually amended once the count is closed (BirdLife Australia, 2020b).

Analysing and disseminating results

Each year, BirdLife Australia generate an engaging infographic to summarise the results of the ABBC, including how many people participated, how many checklists were submitted, how many birds were counted, and a breakdown of the most common species nationally and for each state (BirdLife Australia, 2020a). Species lists for Australia as a whole and for each state and territory are also generated. Both the infographic and species lists are freely available for anyone to download from the ABBC website. Location specific reports are also generated for local councils who contributed to the project via a 'Council Package' (see Role of LGA).

Role of LGA

BirdLife Australia encourages local governments to support the ABBC via 'Council Package' options. LGAs are encouraged to increase community engagement with the project by promoting the project to their local residents. In exchange for this assistance with promotion of the project, BirdLife Australia provide marketing materials free of charge, and include the LGA logo on the ABBC website. It is possible for local councils to participate without a financial contribution, by simply agreeing to help promote the project to their local communities. Alternatively, if local councils also make a small financial contribution, they are provided with a more detailed tailored report of results and raw data from the local area. This benefits BirdLife Australia, the project developer, as this income contributes to the funding of the ABBC each year, including the ability to analyse the data to produce the reports. The detailed report provided to the local government provides tangible benefits as they can use this information and data to assist with environmental programs and management decisions. The Shire of Mundaring has participated at different levels at different times, including financial contributions in 2019 and 2020, and in-kind support via social media promotion and display of posters and flyers.

Benefits of the Project

Scientific Knowledge

The ABBC generates a huge dataset concerning distribution of bird species across Australia, particularly in urban areas and from locations that would normally not be surveyed, such as people's private gardens. The ABBC helps ecologists to track large-scale trends in biodiversity. For example, results so far indicate that birds such as the White Ibis, White-

winged Triller, Crimson Chat, and Pied Honeyeater that are normally found in dry areas of the country have started moving towards wetter areas near the coast, probably in response to continued drought in regional areas. Such trends would be much more difficult to identify without this citizen science project that engages so many people and allows for large amounts of data to be collected across a broad geographic region.

Community Engagement/Environmental Education

Participation in the ABBC gives the general public an opportunity to improve their bird identification skills, and a chance to connect with their natural environment and gain a greater appreciation of our unique fauna. Based on personal experience, participation is very rewarding and gives a sense of achievement, along with the satisfaction of knowing that a small contribution of time and effort is helping with conservation of Australia's birds.

Helen Bryant, Engagement Manager at BirdLife Australia, says that based on evaluation surveys, participation in the ABBC event is associated with increased awareness of conservation issues, and an increased appreciation of birds and their needs. BirdLife Australia has also observed that participants find the event a "great way to connect with nature and they enjoy helping BirdLife Australia develop an understanding of their local birds, whilst they get to know and appreciate their local wildlife" (H. Bryant, 2020, personal communication).

Management

Local data provided to LGAs who opt-in may help councils track the success of their biodiversity management efforts. BirdLife Australia suggest that over time, the data may provide benefits such as; quantifying how local changes such as revegetation projects are impacting bird biodiversity, showing how birds have responded to urban development, or identifying local hot-spots for bird activity which could be promoted to local residents or as part of an eco-tourism plan. These local bird observations can also be used to develop 'backyard biodiversity' programs to help more residents identify what types of wildlife are using their property, and to assist residents to enhance features of their property that provide habitat for wildlife.

Conclusion

Citizen science can be a very effective tool for engaging the public in the scientific process and has many potential benefits for the community and for environmental education. However, there are also limitations that need to be taken into consideration. For example, successful projects require significant input and expertise from a variety of disciplines. Local government authorities and other organisations without the capacity to develop their own citizen science projects can support the success of existing projects by small but valuable contributions. These may include financial assistance, promoting the project via various media, assisting with general and targeted recruitment, providing local venues for information sessions and workshops, and assistance with broad dissemination of results. Another important limitation is that participation is often limited to certain demographic groups, which limits opportunities for broad engagement and broad exposure to environmental education. There is not a 'one size fits all' approach to ensure broad participation; what will work will depend on the barriers to participation that exist in a particular community. Careful planning and development of projects, and comprehensive evaluation of outcomes, is crucial to ensure the potential benefits of citizen science for science and society can be realised.

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