From Streets to Sea:
Evaluating Citizen Science Programs with the Port Phillip EcoCentre

An Interactive Qualifying Project Report submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science.

Submitted by: Nick Bergstrom, Sarah Duquette, Madison Healey, Nick Sorensen

12 December 2017
Melbourne Project Centre

Advisors: Fred Looft, Karen Oates

ABSTRACT

This project was intended to evaluate and improve the Port Phillip EcoCentre Baykeeper street and river auditing programs to enhance their functionality and usefulness when using citizen science. We developed a best practice rubric to evaluate the design of citizen science programs, used the rubric to evaluate the Baykeeper street auditing program, and developed and implemented an improvement plan for the program. We delivered an instructional and promotional video to the EcoCentre for the Baykeeper street litter audit and provided general recommendations on how to apply our project work in the future. This work will further the EcoCentre's mission to educate and advocate on environmental issues. Our project work can also be used by other organizations using citizen science.

Keywords: Baykeeper, Citizen Science, Continuous Improvement, Evaluation, Matrix, Microplastic, Pollution, Port Phillip EcoCentre, Program Assessment, Rubric

EXECUTIVE SUMMARY

Background Overview

Port Phillip Bay is located in Victoria, Australia, immediately south of the city of Melbourne (State Government of Victoria, 2013). The Bay is fed by a catchment region comprised of creeks, rivers, and basins as well as the drainage system of Melbourne's streets (Port Phillip and Westernport Catchment Management Authority, 2012). The bay has a uniquely narrow mouth resulting in the containment of contaminants from the catchment area and protection from contaminants outside of the bay. This makes pollution in Port Phillip Bay uniquely characterisable, as the source is mainly the catchment region.

One of the main pollution concerns in Port Phillip Bay is microplastic pollution, especially due to the number of vulnerable species that inhabit the bay (State Government of Victoria, 2013). Microplastics are small pieces of plastic less than 5 millimetres in size that can harm marine life in a variety of ways. Plastic pollution often starts in the streets of the catchment region and are carried by wind or rain runoff into creeks and rivers.

One of the Port Phillip EcoCentre's (PPEC) programs, entitled "Baykeeper," works to protect the Bay and its catchments from pollution. The Port Phillip EcoCentre is interested in recruiting the help of citizen scientists to work towards reducing microplastic pollution in the Bay. Citizen science provides a platform for researchers and organisations with limited resources to gather long-term data over diverse areas while maintaining high data quality and boosting public awareness. The PPEC has developed auditing methods designed for use with citizen science, recognised by the Environment Protection Authority Victoria (EPA), to facilitate the quantification of microplastics on beaches, streets, and along rivers. The beach auditing method has been adapted and released for use by citizen scientists. However, the EcoCentre had not yet adapted and evaluated the street and river audits. Prior to this project, there was no formal way of evaluating and improving citizen science projects to fully utilise citizen science.

Project Objectives

The goal of this project was to evaluate and improve the Port Phillip EcoCentre's Baykeeper street and river auditing systems to enhance their functionality and usefulness when using citizen science. The objectives were as follows:

1. Develop a best practice rubric for evaluating citizen science programs
2. Critically evaluate the current Baykeeper street and river litter auditing programs using the best practice rubric
3. Develop and implement an improvement plan for the Baykeeper auditing programs based on our evaluation

Rubric Development Process

We developed a best-practice rubric to evaluate citizen science programs by conducting interviews with citizen science experts, participant observation, and user observation. To make the rubric applicable across all citizen science projects, we developed criteria to address aspects of program design rather than project outcomes. To do this, we generated a list of commonly used terms from our interview notes that aligned with key characteristics of citizen science programs. We then identified links between the characteristics and grouped them into three main sections. These sections are Spreading Awareness, Recruitment and Retention, and Scientific Contribution. After deciding upon the three main rubric elements, we generated eleven subelements from our list of key characteristics. We then developed four different descriptions of ranking levels for each subelement to evaluate the citizen science program.

Rubric Implementation

To facilitate the implementation of our rubric, we developed a flowchart describing the process of assessment. It is first necessary to understand each subelement level of the rubric. After understanding the subelement of the rubric and how it relates to the project, the next step is to choose a target level that will represent the highest level possible that the project can realistically achieve. This level will not always be chosen as the mastery Level 3, because it is not always feasible for a project or it may not be a desired area of focus for the project. Once the target level has been identified, the program will be assessed to identify the current level for the subelement. If a program is determined to fall under more than one level for the same subelement, the lower level should be chosen to indicate there is room for improvement. Gap analysis would then occur, and a list of improvements would be made. This process should be repeated for each of the individual subelements in the rubric. The improvements would be then prioritized based on the development of the project and the gaps that were identified between the target and current levels of the project.

Using the rubric and the implementation guide, we evaluated the Baykeeper street litter audit methods to identify areas of improvement. The "Analysis" subelement in Scientific Contribution showed the area for most improvements to be made. However, the "Objective" subelement was ranked as the top priority for the program because without a clearly defined research question, it is unclear how the data would need to be analysed to support the research. From the evaluation of the Baykeeper street litter audit, an improvement plan was created for the EcoCentre to elevate the current status of the program.

Applications of Rubric

Following the creation of the best practice rubric, Neil Blake and Fam Charko at the Port Phillip EcoCentre were consulted to evaluate the Baykeeper street litter audit program. Using the best practice rubric, a target score and current score for each subelement were determined. All target levels were set to be a Level 3, indicating that the EcoCentre staff believes that there are resources available to elevate the program to reach Level 3 in each subelement. None of the subelements are currently ranked at a Level 3, which is largely a product of the infancy of the program. Following preliminary improvements and the release of the program to the public, it is likely that the Baykeeper street audits will immediately score stronger. The evaluation indicates that there is room for improvement in every aspect of the program after implementation as well. The Baykeeper river and creek audit was not evaluated using the rubric because it is not feasible with the current method due to safety and accessibility concerns.

The rubric was designed to assess projects and programs that collect data to contribute to a scientific initiative through the use of volunteers and can be applied to citizen science programs not only within the EcoCentre but also outside of the EcoCentre. Although the focus of the rubric is on projects with heavy emphasis on scientific data collection, citizen science projects designed more to educate or involve volunteers can also be evaluated using the rubric. The rubric is flexible and can be used for continuous improvements through assessments of the categories and subelements.

Recommendations and Moving Forward

We recommend that the rubric be used periodically for re-evaluation and continuous improvement. During the evaluation process, we recommend that persons from each level of the program, volunteers to high-level managers, evaluate the program using the rubric. This will give wider perspective and observation on the current state of the program. Keeping a record of the previous scores will provide a metric for improvement. We recommend using the rubric evaluation when seeking funding to demonstrate a clear continuous improvement strategy and structure.

We discussed the future of our work and the Baykeeper program with the program directors, Neil Blake and Fam Charko. One immediate way they will be using our findings is in support of funding applications. They believe the evaluation and continuous improvement strategy we developed will give credibility to their process and can support funding efforts. This work will also help structure the work of the communication intern team they recently recruited. In the long term, the EcoCentre will use our work in collaboration with other organisations to demonstrate how to run a successful citizen science project.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

CHAPTER 1. INTRODUCTION

Port Phillip Bay, in the southeastern state of Victoria, Australia, is one of many waterways affected by microplastic pollution. An estimated 500,000 or more pieces of plastic enter Port Phillip Bay each year and threaten the marine wildlife (Blake et al., 2014). Previous studies have found significant deposits of microplastics in the bay area, likely coming from the rivers that feed into the bay. Microplastics, shown in Figure 1, are small pieces of plastic less than 5 millimetres in size that can harm marine life in a variety of ways and come from multiple sources. The diversity of sources of microplastics, as well as the broad geographical range they occupy, make the quantification of microplastics in the bay difficult.

Figure 1. Assortment of Nurdles

The Port Phillip EcoCentre (PPEC) is a not-for-profit environmental group in the Melbourne area, shown in Figure 2, which started in 1999 working to promote community involvement, education, and sustainability. One of their ongoing goals is to keep the Port Phillip Bay clean, and free of microplastic pollutants. The PPEC has been working on a project to quantify the extent of plastic pollution in Port Phillip Bay and the surrounding catchment area and to identify the primary sources of this pollution. This project, known as Baykeeper, is the first step in the PPEC's mission to advocate for the reduction of microplastic pollution.

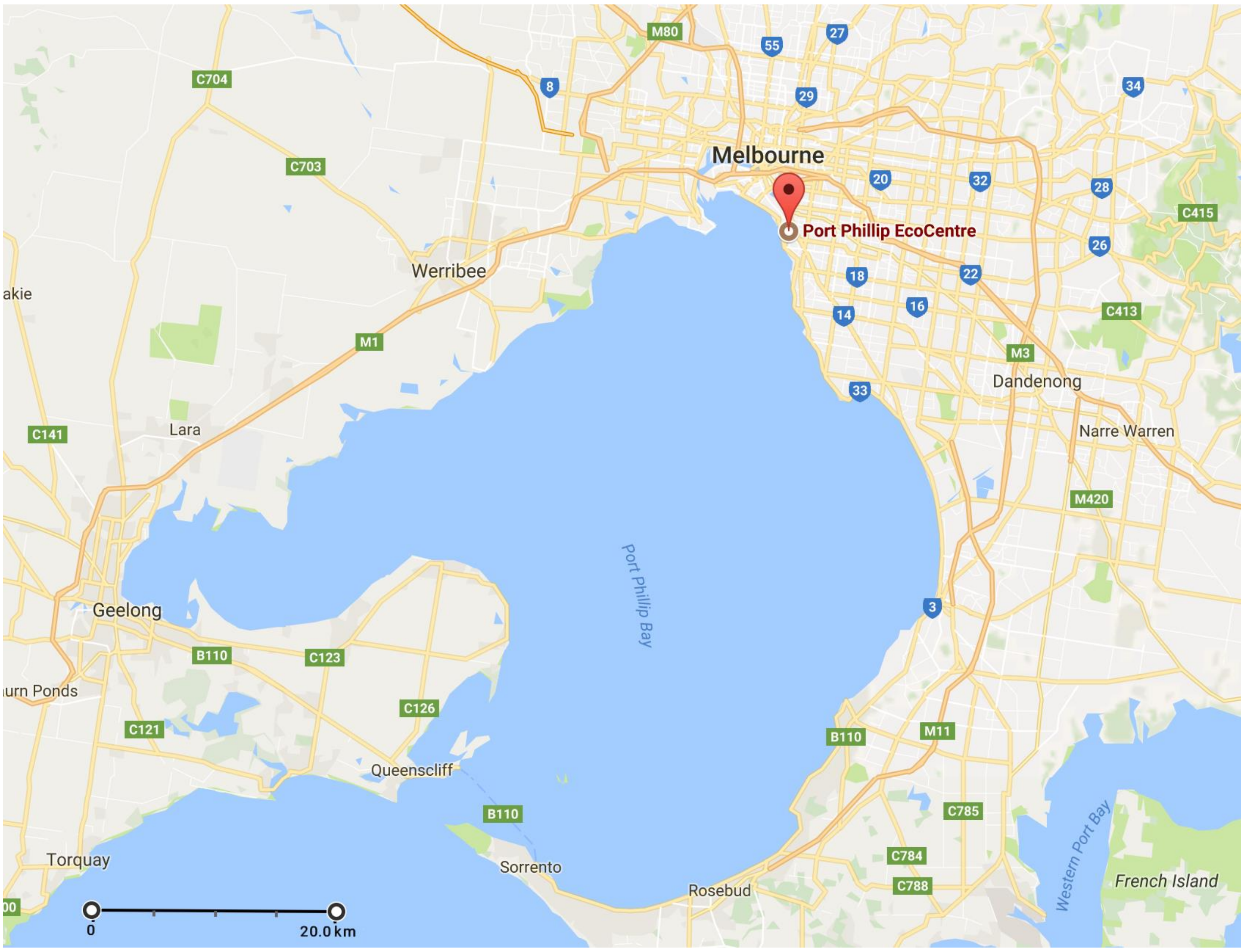


Figure 2. Port Phillip Bay and EcoCentre, Labelled (Google Maps, 2017)

To work towards reducing microplastic pollution in Port Phillip Bay, the Port Phillip EcoCentre is interested in recruiting the help of citizen scientists. The PPEC has developed auditing methods, recognised by the Environment Protection Authority Victoria (EPA), to facilitate the quantification of microplastics on beaches, streets, and along rivers. A previous team of Worcester Polytechnic Institute (WPI) students worked in collaboration with the PPEC to adapt and release the beach auditing method for use by citizen scientists. However, the EcoCentre had not yet adapted and evaluated the street and river audits.

The goal of this project was to evaluate and improve the street and river auditing systems to enhance their functionality and usefulness when using citizen science. To accomplish this goal, we conducted extensive background research on pollution, microplastics, and citizen science, developed a best practice rubric for assessing citizen science programs, evaluated the PPEC's litter audits using our best practice rubric, and provided an improvement plan based on our evaluation. With the fulfillment of these objectives, we provided recommendations to the PPEC on how to optimize the street auditing program for use with citizen science. We released our findings to citizen science experts in the Melbourne area so that they could evaluate their own programs for scientific contribution. Ultimately, the release of the audits will promote sustainability within the community and increase the likelihood of legislative approval regarding plastic use and pollution.

CHAPTER 2. LITERATURE REVIEW

To understand our project, it was necessary to first familiarise ourselves with microplastic pollution in Port Phillip Bay and previous citizen science projects. This chapter covers topics relevant to the research of microplastic pollution in Port Phillip Bay using citizen scientists. We describe Port Phillip Bay, introduce the Port Phillip EcoCentre, identify key stakeholders, provide an in-depth explanation on microplastics and the best methods for studying them, and discuss citizen science and its application to this project. The review concludes with two archival case studies which used citizen scientists and their applications to this project.

2.1 Port Phillip Bay Site Description

Port Phillip Bay is a 2,000-square kilometre body of water in Victoria, Australia, immediately south of the city of Melbourne (State Government of Victoria, 2013). The bay is home to Australia's busiest port, the Port of Melbourne. Along with supporting recreational boating, watersports, and shipping routes, Port Phillip Bay is also home to nearly 10,000 species of marine life including 43 threatened species (Port Phillip Bay, 2009; State Government of Victoria, 2013).

The Bay is fed by a catchment region, highlighted in Figure 3, comprising 10,000 square kilometres of creeks, rivers, and basins as well as the drainage system of Melbourne's streets (Port Phillip and Westernport Catchment Management Authority, 2012). The most significant source of water flowing into the bay from the mainland is the Yarra River, which runs through the city of Melbourne (State Government of Victoria, 2013). The freshwater in the catchment region is collected and used as a source of water for drinking and various industrial purposes (Port Phillip and Westernport Catchment Management Authority, 2012). The bay has a uniquely narrow mouth resulting in the containment of contaminants from the catchment area and protection from contaminants outside of the bay. This makes pollution in Port Phillip Bay uniquely characterisable, as the source is mainly the catchment region.

Figure 3: Bay and Catchment Region with Labelled Waterways (Melbourne Water, 2017)

Microplastic pollution is a growing problem and concern in Port Phillip Bay, especially considering the number of vulnerable species that inhabit the bay (State Government of Victoria, 2013). Plastic pollution often starts in the streets of the catchment region. Contaminants, such as plastic litter and polystyrene beads, on the street are carried by wind or rain runoff into creeks and rivers. The two primary inlets which carry microplastics into the Port Phillip Bay are the Yarra and Maribyrnong Rivers (Blake et al., 2014).

The Port Phillip EcoCentre (PPEC) works to protect and preserve the Bay and its catchments. The mission of the PPEC is to spread awareness of environmental issues through educational programs directed towards the public and to address these issues by involving the community to take action. Civilians and scientists, such as marine biologists, work for the PPEC on programs to protect the bay area. One of their programs, entitled “Baykeeper,” is designed to protect the Port Phillip Bay from pollution. The Baykeeper program has piloted a variety of measures that can track down the source of the contaminants and increase public awareness. These measures include providing educational outreach for the community on pollution problems, tracking marine life and the quality of water, performing litter audits, and advocating for cleanup measures (About Baykeeper, 2017).

2.2 Stakeholder Profiles

The initiatives to support counter-pollution measures have brought together city planners, experts, local agencies, and volunteers. Without these engaged stakeholders, the Baykeeper project cannot leverage enough resources for data collection. Our project will engage volunteers, citizen science experts, and environmental management agencies. Volunteers are the most diverse group of stakeholders, encompassing schoolchildren to seniors from all backgrounds. The volunteers have differing reasons for involvement including merit badges, school projects, interest in making a difference, contributing to science, socialisation, or any combination of reasons.

To fully utilise volunteer participation in our project, we consulted with citizen science experts including researchers at the PPEC as well as citizen science researchers from the wider community. The PPEC, along with other organizations, will be invested in our findings regarding microplastic and citizen science research. The citizen science experts and the PPEC received our recommendations and report.

2.3 Microplastics: Pathways and Monitoring Challenges

Microplastics are particles or beads of plastic measuring less than 5 millimetres (Lerner et al., 2014). Marine microplastic pollution has become a growing concern due to their effects on wildlife. When marine wildlife ingests these particles, the plastic can accumulate in the digestive tract, leading to starvation (Gregory, 2009). Microplastics can also absorb toxic compounds, known as persistent organic pollutants (POPs), from seawater (Andrady, 2011) and although POPs occur naturally in seawater in low concentrations, they are absorbed by microplastics in high concentrations and released as toxins upon ingestion (Gregory, 2009). These toxins can cause reproductive complications, starvation, and threats to survival for many species (Gregory, 2009). An estimated 40% of marine bird species ingest plastics, with some birds having been seen feeding their offspring plastic pellets (Andrady, 2011). Microplastic-released toxins consumed by birds and marine organisms can be cycled through the marine ecosystem, contaminating the marine food chain and ultimately introducing these toxins into the seafood that humans consume (Clark et al., 2016).

Microplastic fragments enter the marine ecosystem through rain runoff, sewer systems, rivers, and the degradation of other products (Clark et al., 2016). Sources of microplastics include microfibres from synthetic clothing, fragments from larger products, pellets, or “nurdles,” used to produce larger plastic products, and microbeads found in cosmetics (Pirc et al., 2016; Cole et al., 2011a; Wright et al., 2013).

A common mode through which microplastics enter wastewater is through synthetic clothing that releases fibres when washed. Synthetic fibres, when separated from the original clothing source, are also considered to be microplastics. A microfibre fleece blanket releases an average of 0.0012 % of fibres per wash into the wastewater of a standard washing machine

(Pirc et al., 2016). As a result, a 6 kg wash load will release an average of approximately 700,000 fibres (Napper et al., 2016). Due to the small size of these fibres in proportion to the washing machine filter, the fibres are not filtered out of the wastewater and ultimately release into the environment. A standard dry cycle will release approximately 3.5 times the amount of fibres released from a washing machine (Pirc et al., 2016).

When larger plastic items or macroplastics, such as plastic straws, enter the marine environment, they can degrade due to ultraviolet radiation, oxidation, photodegradation, and mechanical abrasions or a combination of these (Ryan et al., 2009). Macroplastics fragment into even smaller particles that marine organisms can then ingest (Jambeck et al., 2015). Due to their size, it is difficult to remove fragmented macroplastics from the oceans. Therefore, reducing the sources of inputs is the most effective strategy of microplastic elimination (Jambeck et al., 2015).

While some microplastics form as a result of washing, or forms of degradation, others are manufactured and designed to be microplastics. Manufactured microplastics are often called nurdles and include resin plastic pellets and microbeads found in cosmetics such as facial cleansers. Microbeads in facial cleansers have replaced the use of natural ingredients such as oatmeal and pumice. These small spheres are used by the consumer and then washed down a drain where, due to their size, they are not filtered out of the wastewater that eventually feeds into the oceans (Cole et al., 2011). Another manufactured microplastic, plastic resin pellets, sometimes called “virgin pellets,” degrade faster since they do not contain ultraviolet stabilisers found in larger plastic products (Andrady, 2011). Virgin pellets “clean” the ocean of toxins through absorption, but when organisms ingest these pellets, the toxins release into their bloodstreams which can be deadly (Andrady, 2011).

To understand the extent of microplastic pollution, scientists have conducted studies on surveying techniques to identify and quantify microplastics. Three common approaches for sampling microplastic pollution in a marine environment are bulk, selective, or volume-reduced sampling (Hidalgo-Ruz et al., 2012). These surveying methods are valid for sea surface, water column, and sediment sampling. Bulk sampling is a method in which the sample size remains constant without reduction (Hidalgo-Ruz et al., 2012). Thus, an entire sampling area would be taken from the sample site to an external location and then separated for further analysis. Bulk sampling is useful when the eye cannot easily identify the microplastics because of the size of particles or due to the sheer number of particles in a given sample. A sorting or sifting method is required to filter out these fragments. Sieving through a large area on a beach is an example of bulk sampling. Selective methods involve visual inspection and identification of microplastics by the naked eye (Hidalgo-Ruz et al., 2012). This method is most common because the size of microplastics ranges from one to five millimetres. The selective method as compared to bulk selection runs the risk of overlooking potential microplastic pollution as all collected microplastics have been handpicked from a defined and selective sample space (Hidalgo-Ruz et al., 2012). Finally, volume-reduced sampling is valid for both seawater and sediment, where the sample size is reduced to the necessary material (Hidalgo-Ruz et al., 2012). Volume-reduced sampling of sediment usually involves sieving of material directly (Hidalgo-Ruz et al., 2012).

A common volume-reduced sample method is the use of a manta trawl to collect microplastics directly from seawater (as shown in Figure 4 below). The image below shows an example of a manta net used in volume reduced sampling of rivers. This particular one was used to collect samples while being dragged behind a boat. This same device can be used to collect samples at different defined depths (Solomon et al., 2016). This approach, in particular, requires much less sample preparation because the bulk of the material captured in the net is desired data.

Figure 4: Manta Trawl (Oluniyi Solomon & Palanisami, 2016)

All of the sampling methods described previously can be used to quantify the amount of microplastic pollution in a given environment. Volume reduced and selective sampling methods, in particular, have been used to collect and measure levels of microplastics in the Port Phillip Bay (Blake et al., 2014). Sampling methods that the EcoCentre has used in the past for the Port Phillip Bay audits include selective and volume-reduced (Blake et al., 2014). Their volume-reduced sampling method involved using a boat to trawl with a manta net in predetermined river and bay area locations for 30 minutes at a time (Blake et al., 2014). In a 2014 study conducted by two researchers at the EcoCentre, Neil Blake and Fam Charko, it was found that an estimated 580,000 and 500,000 plastic pieces per year are carried into the bay area by the Yarra and Maribyrnong Rivers respectively (Blake et al., 2014). However, the width of the rivers is at least 166 times wider than the net used to collect samples of plastics, almost certainly resulting in an underestimate of plastic pieces (Blake et al., 2014).

The EcoCentre uses a selective sampling process for beach auditing due to the smaller size of the microplastics and the reduced sample size. This method involves sampling several areas of beach each comprising of only one square meter of surface sand. In March 2017, a team of students worked with the Port Phillip EcoCentre on Baykeeper to release this method for use by citizen scientists (Bayas et al., 2017). Similar methods have been developed for audits in streets and rivers. These methods have not yet been released to citizen scientists.

2.4 Citizen Science in Long-Term Ecological Research

Citizen science, or volunteer research and data collection, provides a platform for researchers and organisations with limited resources to gather long-term data over diverse areas while maintaining high data quality and boosting public awareness. Scientists have increasingly relied upon citizen science to foster public engagement (Bonney et al., 2014). Citizen scientists have collected data on a variety of topics from counting birds in a given area to water quality monitoring to galaxy characterisation (Done et al., 2017; BirdLife Australia, 2017).

The diversity of research capabilities makes citizen science a desirable strategy for many ecological and environmental studies (Dickinson et al., 2012). When researchers have limited resources, it can be especially difficult to collect data across broad geographical areas and over long periods of time (Cigliano et al., 2015). Due to the inexpensive nature of citizen science, and the diverse nature of the participants regarding residential location, citizen scientists provide the possibility for the collection of long-term data over a broad area (Cigliano et al., 2015). Scientists can then use this long-term data to determine trends they would not have otherwise been able to identify. In an environmental and ecological context, these trends are especially vital as they work to discriminate between periodic shifts and episodic events, allowing for a more confident response to episodic events (Cigliano et al., 2015).

A secondary benefit of citizen science use is its impact on public perception and public education on ecological and environmental issues. Because citizen science requires direct public participation, it fosters widespread education on the ecological or environmental issue at stake and increases investment on the part of the public (Dickinson et al., 2012). The education and investment can further the mission of managers and scientists to understand and respond to ecological and environmental problems which often require public support (Dickinson et al., 2012).

Data quality must also remain a high priority because the "utility and uptake of [data collected through] citizen science in a policy and management context" can be stifled by negative perceptions of the quality of data collected (Vann-Sander et al., 2016). According to researchers at the University of Western Australia, the three primary drivers of data quality in citizen science projects are methods of data collection, training, and quality assurance and quality control protocols (Vann-Sander et al., 2016). Shown in Figure 5 below are a variety of other factors which influence data quality. Designing a study with these factors in mind is essential. The involved factors are all dependent on one another, and a strong citizen science project will exceed in each.

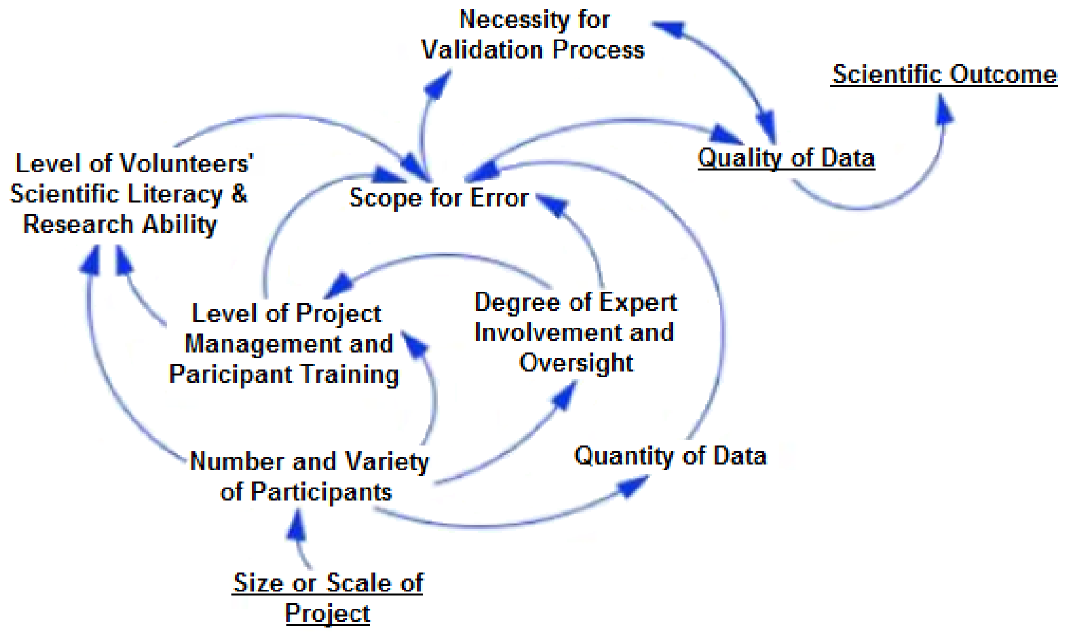


Figure 5: Influence of Study Design Factors on Data Quality (Modified from Vann-Sander et al., 2016)

A study designed around the factors shown in Figure 5 has the potential to generate high-quality data. This research is supported by case studies we reviewed.

2.5 Case Studies

We reviewed two case studies that use citizen scientists. The first, Reef Check Australia, is a local project in Australia, and the second, Cientificos de La Basura, took place in Chile. We examined these studies to gain insight on how environmental groups use citizen science to generate high-quality data.

<u>Case 1. Reef Check Australia Citizen Science:</u> Since 2002, Reef Check Australia (RCA), a nonprofit group dedicated to conservation and education surrounding the reefs off the Queensland coast, has used citizen science to monitor the benthic zone composition of reefs. This study spanned over 70 sites and over 1,000 km of coastline (Done et al., 2017). The benthic zone is defined as anything on the bottom of a body of water (What is a Benthic Habitat Map?, 2017). The RCA monitoring protocol involves extrapolating the composition

in terms of percentage covered by categories of benthic structures (for example, corals, algae, and sponges). The protocol is based on observations made by volunteer divers at specified points along transect lines laid out on each deployment (Done et al., 2017). To achieve high-quality data, this method requires competency in the representation of benthic categories by volunteers. The volunteers are required to attend standardised training and pass exams based on identification to ensure competency (Done et al., 2017).

In 2016, researchers from the Australian Institute of Marine Science and RCA conducted a study on the reliability and utility of data collected in the program from 2002-2015 (Done et al., 2017). To determine the accuracy of the monitoring method, RCA researchers used simulation with virtual reefs of known composition (Done et al., 2017). They designed virtual reefs as sets of points of different values representing different benthic categories with a random distribution, but known percentages (Done et al., 2017). Then, the researchers measured the data set in the same way as the monitoring method, by taking observations of the category existing at specific points on transect lines and extrapolating (Done et al., 2017). Researchers then compared the extrapolation to the actual composition, and found that at higher compositions the accuracy was lower, but remained at ±6% (Done et al., 2017).

Precision was investigated along the lines of three modes of error: observer error, deployment error and error due to the heterogeneity of benthic substrata across sites (Done et al., 2017). Observer error was tested by keeping the transect line fixed during observation by multiple observers, keeping the points of observation constant and only changing the observer (Done et al., 2017). Deployment error, or error caused by minor differences in the placement of the transect line, was tested by using the same observers to observe a transect line multiple times across multiple deployments (Done et al., 2017). Error due to the heterogeneity of benthic substrata was tested by comparing precision between diverse sites (Done et al., 2017). These modes of error contributed to less difference than real differences between the sites (Done et al., 2017). Relationships were also derived between the extent of error and types of benthic substrata (Done et al., 2017).

Overall, the study found that despite multiple possible sources of error, using citizen science was highly effective in generating high-quality data (Done et al., 2017). This study also determined the baseline of variation from which to measure real change (Done et al., 2017). Quality studies like this one create value by verifying data quality and quelling stakeholders' possible negative perceptions of data based on citizen science. This study also lead to the evolution of the methodology to foster higher quality data (Done et al., 2017). This case study showed the importance of the need for data quality to be evaluated in a citizen science project.

Case 2. Litter Sampling in Chile uses Citizen Science: A 2014 study involving the group Cientificos de la Basura (Litter Scientists) investigated the quantity and types of litter at different sites along four rivers in Chile using the help of schoolchildren and their teachers as citizen scientists (Rech et al., 2015). The schoolchildren, who between 10 and 15 years old, were supervised by local marine scientists and given instructional guidebooks (Rech et al., 2015). Data were collected at several sites from the headwater to the mouths of the rivers and on the bank from the river's edge past the high water mark (Rech et al., 2015). The study was only concerned with litter over 15 millimetres in length (Rech et al., 2015).

The study used separate professionally collected samples of litter as a baseline, and the researchers claim that the citizen scientists' data was reliable, despite discrepancies in the data between professionals and citizen scientists (Rech et al., 2015). The researchers explained that the discrepancies are due to differences in climatic conditions between the collection periods of the professionals and citizen scientists. The citizen scientists sampled the areas after the rainy season and professionals sampled the areas before the rainy season (Rech et al., 2015). The quality assessment of the collected data is therefore invalid because the sampling time was not controlled. Compared to the Reef Check study which included three controlled precision tests, which tested three potential modes of error and an accuracy test, the Chile litter study's quality evaluation is unsupported. These studies showed that high-quality data is achievable using citizen science, but the program must be designed and the results presented in a way that ensures and garners confidence in quality.

2.6 Summary

Plastic pollution not only leaves recreational areas looking dirty and unsanitary, but it harms marine life. With the information our team has gathered, we have developed an understanding of the types and causes of microplastic pollution, and the negative impacts the pollution has on the Port Phillip Bay. Results from the case studies helped us better understand how to evaluate the accuracy of the data collected by citizen scientists as well as how to continuously improve a citizen science project. To further help with the process of identifying litter sources through audits, our team developed a best practice rubric, used the best practice rubric to evaluate the audits, and provided an improvement plan based on our findings.

CHAPTER 3. METHODOLOGY

The goal of this project was to evaluate and improve the Port Phillip EcoCentre's Baykeeper street and river auditing systems to enhance their functionality and usefulness when using citizen science. The objectives were as follows:

1. Develop a best practice rubric for evaluating citizen science programs
2. Critically evaluate the current Baykeeper street and river litter auditing programs using the best practice rubric
3. Develop and implement an improvement plan for the Baykeeper auditing programs based on our evaluation

The methods described below are based in part in part on the information provided by Kevin Ward in *Researching the City* and Bruce Berg in *Qualitative Research Methods for the Social Sciences* (Ward, 2014; Berg, 2012).

3.1 Develop a Best Practice Rubric for Evaluating Citizen Science Programs

To evaluate and improve the Baykeeper street and river auditing systems to enhance their functionality and usefulness when using citizen science, a best practice rubric was developed for evaluating the design of citizen science programs. The rubric was developed using interviews and participant observation.

3.1.1 Interviews

Eleven experts in citizen science (shown in Table 1) were interviewed. Together these experts represent the coordinating level of citizen science project operation and encompass a broad range of projects with different emphases. Their contact information can be found in Appendix A. These interviews were focused on key characteristics of a successful citizen science project. Interview guides can be found in Appendix B. The interviews were coded and a list of key characteristics was generated. These key characteristics were linked and fell into natural groupings and subgroupings representing the main elements and subelements found in the rubric.

Table 1. Interviewees and Their Roles

Kade Mills	ReefWatch Coordinator at the Victorian National Parks Association and directs the annual Great Victorian Fish count, a long-term citizen science project
Ray Lewis, OAM	Pioneer of marine citizen science in Australia and works with Marine Care Rickett's point, a group which monitors the reefs of Rickett's Point
David Mossop	Coordinator of citizen science at the Victorian Environmental Protection Agency
Ross and Ramona Headifen	Members of Beach Patrol and have conducted their own litter audits of First Point Beach in Port Melbourne over the past two years
Fam Charko	Marine biologist working on citizen science projects at the EcoCentre and with Tangaroa Blue
April Seymore	Executive Officer of the EcoCentre and has worked extensively on environmental education programs
Donna Sheil	Facilitator at the Victorian Litter Action Alliance which has conducted a citizen science based microplastic project
Nicole Kowalczyk	Yarra Riverkeeper and has used students for litter data collection
Jill Sokol	Founder of Love Our Street which audits street litter using citizen scientists
Neil Blake, OAM	Port Phillip Baykeeper and is in charge of the EcoCentre's Baykeeper litter audits
Kylie Andrews	Award-winning journalist for the ABC and a committee member for the Australian Citizen Science Association

3.1.2 Participant Observation

Participant observation was conducted to gain an understanding of citizen science projects from a citizen scientist's perspective. We participated in four programs: the Baykeeper beach audit and street audit, the Great Victorian Fish Count, and Beach Patrol St. Kilda. These programs were chosen because each has a different focus. Beach Patrol is highly focused on community involvement, whereas the Fish Count and Baykeeper audits are concentrated on scientific rigor and data collection. This participation provided support for the key characteristics of citizen science projects identified by experts in the interviews.

3.2 Critically Evaluate the Current Baykeeper Street and River Litter Auditing Programs Using the Best Practice Rubric

To enhance the Baykeeper street and river litter auditing programs functionality and usefulness when using citizen science, the best practice rubric was used for evaluation. This evaluation was completed based on participant and user observations and roundtable discussions.

3.2.1 Participant Observation

We began by participating first-hand in the street and river litter audits that the EcoCentre developed. While conducting the litter audits, any difficulties and possibilities for improvement were noted. Conducting the audits with the rubric in mind encouraged us to focus on the important components of citizen science projects and identify where the EcoCentre's methods excelled or needed improvement.

3.2.2 User Observation

To obtain a balanced assessment of the street and river litter audit programs, we utilised user observation to determine difficulties that citizen scientists face during the data collection and training and the positive aspects of the program. We watched groups of citizen scientists learn how to perform the street litter audits for the first time. During our observations, we took note of participant behaviour and any possible improvements to the training and methods.

3.2.3 Roundtable Discussions

Two roundtable discussions were conducted. The first was conducted with the participants we observed completing the street audit. This discussion focused on the difficulties they faced and what could be improved about the methods, training, and training materials from the citizen scientist's perspective. The second was conducted with the directors of the program and focused on evaluating the program as a whole using the rubric. Through this discussion, we determined the target levels for the program and the levels of the current state of the program. This discussion with the directors was structured using the subelement criteria in Appendix C and the process shown in Appendix D. The worksheet in Appendix E was used to note conclusions.

3.3 Develop and Implement an Improvement Plan for the Baykeeper Auditing Programs Based on Our Evaluation

To enhance the Baykeeper litter auditing programs for functionality and usefulness when using citizen science, an improvement plan was developed based on the evaluation. This improvement plan was based on the synthesis of findings and roundtable discussions with the program directors.

3.3.1 Synthesis

All notes from user observations, roundtable discussions with citizen scientists, and participant observations, including comparisons between the Baykeeper program and outside programs, were synthesised. Many of the questions that were asked of citizen scientists can be found in Appendix F. From these observations and roundtable discussions a list of potential improvements was created.

3.3.2 Roundtable Discussions

A roundtable discussion was conducted with the directors of the Baykeeper program and focused on evaluating the program as a whole using the rubric and developing improvement strategies for each subelement of the project. Through this discussion, we determined the gaps in the program and how those gaps could be filled. This discussion was structured as shown in Appendix D using the Citizen Science Program Evaluation Worksheet found in Appendix E. Attention was given to the suggested improvement strategies which were then prioritized.

CHAPTER 4. RESULTS AND DISCUSSION

To achieve the goal of this project, a best practice rubric was developed for evaluating the design of citizen science programs. Following the rubric's creation, the Baykeeper street and river litter auditing programs were critically evaluated and an improvement plan for the Baykeeper street and river auditing programs was developed and implemented. Below is a description of the specific results that were achieved for each objective, along with a discussion on how the goal was achieved and the future applications of the rubric.

4.1 Results

All three objectives were successfully completed, leading to achievement of the project's goal. The following are the results achieved for each objective.

4.1.1 Develop a Best Practice Rubric for Evaluating Citizen Science Programs

Based on the interviews that were conducted, summaries of which can be found in Appendix G, we were able to develop a best practice rubric. The main sections or elements of the rubric, found in the leftmost column of the rubric, are Spreading Awareness, Recruitment and Retention, and Scientific Contribution. A three-page version of the rubric can be found in Appendix H.

Spreading Awareness refers to the outreach of the project. This section involves how the project is promoted and how it is used to educate the public on the subject at hand. Spreading awareness was further divided into three subelements: Content, Delivery, and Vehicle. Content refers to the content of the message. When spreading awareness on a topic, the ideal situation for the content of a marketing campaign is to have a project which directly addresses a popular subject. Delivery refers to how the content is conveyed to the public. The ideal delivery method involves divulging the long-term vision or what the ultimate goal of the project is by using a story that taps into the emotions and values of individuals. Vehicle refers to the medium through which the message is delivered. In an ideal situation, the message is delivered via all possible vehicles and each message is tailored to the demographic target through each medium. A high score in Spreading Awareness indicates that the project is working well regarding general outreach and the educational aspect of the project is strong.

The second element, Recruitment and Retention, refers to how the project attracts volunteers and keeps them coming back. Recruitment and Retention is divided into four subelements: Sourcing, Motivation, Investment, and Return. Sourcing refers to the sources of volunteers. It is ideal to recruit volunteers from a variety of different sources which provide opportunities for networking. Motivation refers to the volunteers' reason for participation and their drive to participate repeatedly. Ideally, a project creates a sense of community based on values and leads to the recruitment of other volunteers. It is also important for the volunteers to be invested in the research question and the subject addressed by the project. Investment refers to the effort and time required by volunteers. An ideal citizen science project would require very little time and effort from volunteers and require very little background knowledge or experience. Return refers to what the volunteers receive in return for their efforts. It is important for a project to have an immediately satisfying result, e.g., the amount of litter collected on that specific day, and accessible long-term results which can be used to track progress. Ideally, a project would also include promotional incentives such as discounts, t-shirts, or food. When volunteers are recruited from other organisations, it is important to offer participation or assistance with that organisation's programs to reciprocate. A program with a high score in Recruitment and Retention would have success in finding and keeping volunteers and be able to collect data over an extended period.

The final element, Scientific Contribution, refers to how the project contributes to scientific research on the subject at hand. We divided Scientific Contribution into four subelements: Objective, Quality, Analysis, and Sustainability. Objective refers to the scientific objective of the project. It is necessary to clearly define the research question and qualify it based on any possible limitations, ensuring that the methods of data collection produce data which can be used to answer the research question. Quality refers to the precision and accuracy of the data collected by volunteers. Precision would be guaranteed by using standardised methods and instruction to ensure repeatability, and developing a quality control standard. The accuracy of the methods should be tested in the piloting phase of the project and will be unique to each project. Analysis refers to how the data is analysed. It is crucial to analyse data in a standardised way with reference to a baseline created by a pilot study or through an external benchmark. It is also important to determine and take into account the quality of the data. Sustainability refers to how well a project can be sustained. It is crucial to disseminate findings to the scientific community and the public at large to gain feedback which can be used for continuous improvement. Cross-training staff members on the project will decrease the dependency of the project on a single individual. A project with a high score in Scientific Contribution should produce results which expand the scientific understanding on the subject.

Table 2. Citizen Science Best Practice Rubric

Element	Subelement	Level 0	Level 1	Level 2	Level 3
Spreading Awareness	Content	The project covers an obscure topic and shows no path to positive outcomes. The project misses vital opportunities to leverage current or past events.	The project covers a relatively obscure topic. The goals of the project are vaguely defined with some path to a positive outcome.	The project covers a relatively well-known topic and is able to show a somewhat clear path to a positive outcome. Occasionally leverages events to further interest in project.	The project relates clearly to a popular subject and its goals show a clear path to a positive outcome. The project is able to leverage events local and abroad, as appropriate, in a meaningful and effective way.
	Delivery	The audience is not informed of the project vision, there is no accompanying story to be inspired from, and the project does not align with the audience's values.	Some of the audience is informed about some of the project vision, there is a small accompanying story to be inspired from, and the project aligns with some of the audience's values.	Most of the audience is informed about most of the project vision, there is an accompanying story to be inspired from, and the project aligns with most of the audience's values.	The purpose and long-term vision of the project is clearly laid out to the whole audience with a story which inspires interest and emotional response by aligning with the audience's values.
	Vehicle	Information is delivered through very limited outlets. Communication is very sparse and irregular. Information is not tailored to different demographics or only targets a specific audience.	Information is delivered through limited outlets. Communication is limited and irregular. Information is sometimes tailored to different demographics.	Information is delivered somewhat regularly through several vehicles and is often tailored to the demographic using each vehicle.	Information is delivered periodically through diverse vehicles including social media, printed news, email, conferences/speeches, and newsletters, and is tailored to the demographic using each vehicle.
Recruitment/Retention	Sourcing	Volunteers all come from a similar demographic and random inconsistent sources. The volunteers do not come from organisations/networks.	Volunteers come from similar demographics and a few inconsistent sources. Some volunteers come from organisations/networks.	Volunteers come from various demographics and a few consistent sources. Most volunteers come from organisations/networks.	Volunteers come from a diverse pool of consistent sources and come from organisations/networks.
	Motivation	This project does not create a sense of community among participants and does not facilitate the sharing of values, goals, and a vision. Participants are not engaged in answering the research question.	This project sometimes creates a small sense of community among participants and sometimes facilitates the sharing of values, goals, and a vision. Participants are sometimes engaged in answering the research question.	This project often creates a sense of community among participants and allows for the sharing of values, goals, and a vision. Participants are usually engaged in answering the research question.	The project creates a community among participants, sharing values, goals, and a vision which leads to repeated participation and effortless recruitment. Participants are aware of the research question and committed to answering it.
	Investment	There is a large time commitment and effort required. Training is long and complex and lacks follow up support. There is a high barrier to entry.	There is a large time commitment and effort required. Training is somewhat long and complex and there is limited follow up support. There is a significant barrier to entry.	There is a moderate time commitment and effort requirement. Training is mostly basic and easy to follow and follow up support is provided. There is a low barrier to entry.	The project requires minimal time commitment and is not effort intensive. Training is brief, there is consistent follow up support and methods are simple. There is no barrier to entry.
	Return	The results for the project are not immediately tangible and the data is not accessible to show progress. There is no tangible reward or cross-organisational reciprocity and very limited social interaction.	The results for the project are sometimes tangible and the data is not easily accessible to show progress. There is little tangible reward, social interaction, and cross-organisational reciprocity.	Some results for the project are immediately tangible and most of the data is easily accessible to show progress. There is significant tangible reward, social interaction, and cross-organisational reciprocity.	The project produces immediately tangible results as well as accessible data which provides long term progress visibility. There is a high level of tangible reward, social interaction, and cross-organisational reciprocity.
Scientific Contribution	Objective	The scientific objective of this project is undefined and does not align with research questions and does not account for limitations. Methods don't produce data that fulfills this objective.	The scientific objective of this project is somewhat defined and partly aligns with the research question and some limitations are accounted for. Methods produce some data that fulfil the objective.	The scientific objective of the project is defined based on the research questions and most of the limitations involved. Methods produce data which mostly fulfil this objective.	The scientific objective of the project is well defined based on the research questions and any and all limitations involved. Methods produce data which completely fulfills this objective.
	Quality	Methods and training are complex, difficult to understand, and not regulated for standardisation. No initial quality control is conducted. Training materials do not promote a deeper understanding of the project and don't emphasise scientific rigor.	Methods and training can at times be complex, difficult to understand, and not completely regulated for standardisation. Very little initial quality control is conducted. Training materials sometimes promote a deeper understanding of the project and have minimal emphasis on scientific rigor.	Methods, training, and accompanying materials are often simple, clear, and standardised. Some preliminary quality control protocol is in place. Training materials frequently promote a deeper understanding of the project, methods and have an emphasis on the need for scientific rigor.	Methods, training, and accompanying materials are simple, clear, and standardised. A preliminary quality control protocol is in place. Training materials always promote deeper understanding of the project, methods, and have a large emphasis on the need for scientific rigor.
	Analysis	There is no benchmark to reference data against, and data is not analysed in a standard way. Data quality is not accounted for.	Data is sometimes analysed in a standard way. Data quality is sometimes accounted for. The baseline or outside benchmark is not always accurate.	Data is most often analysed in a standard way. Data quality is usually accounted for. The baseline or outside benchmark is mostly accurate.	Data is analysed with reference to a preliminary baseline or outside benchmark in a standarised way by experts. Data quality is analysed and accounted for.
	Sustainability	Public has no knowledge of the findings and there is no opportunity to provide feedback. Roles are complex and crucial personel are not replaceable. Project has no access to ongoing resources.	Public is aware of some of the findings and are provided an opportunity to give feedback. Some roles are complex and there is minimal cross training. Project has limited access to ongoing resources.	Public has knowledge of most of the findings and feedback may be taken into consideration when making improvements. Few roles are complex and there is some cross training of crucial individuals. Project has sufficient acccess to ongoing resources.	Findings are transparently disseminated to the public and the scientific community and feedback is incorporated. Individual roles are simple and crucial personnel are cross-trained to ensure replaceability. The project has access to a surplus of ongoing resources.

4.1.2 Critically Evaluate the Current PPEC Street and River Litter Auditing Programs Using the Best Practice Rubric

Following the creation of the best practice rubric, Neil Blake and Fam Charko at the Port Phillip EcoCentre were consulted to evaluate the current Baykeeper street litter audit program. The rubric was not used to evaluate the river litter audits because that program was not fully developed at the time. Using the best practice rubric, a target score and current score for each subelement were determined. After much discussion, every target score was ultimately set to be Level 3.

None of the subelements for the Baykeeper street litter audits scored a Level 3 at the time of evaluation. Table 2 shows the scores that the audits achieved in each subelement. Appendix E contains our Citizen Science Program Evaluation Worksheet that was developed to help record target and current project scores when using the rubric.

Table 3. Evaluation Scores

Element	Subelement	Target	Current
Spreading Awareness	Content	3	1
	Delivery	3	1
	Vehicle	3	2
Recruitment and Retention	Sourcing	3	2
	Motivation	3	2
	Investment	3	2
	Return	3	1
Scientific Contribution	Objective	3	1
	Quality	3	2
	Analysis	3	0
	Sustainability	3	1

4.1.3 Develop and Implement an Improvement Plan for the Current PPEC Street and River Auditing Programs Based on Our Evaluation

Table 4. Citizen Science Program Evaluation: Baykeeper Street Litter Audit

Element	Subelement	Target Level	Current Level	Ways to Improve	Priority Ranking
Spreading Awareness	Content	3	1	Show connection of microplastics to the streets, need good funding, raise more awareness, use news events better	2
	Delivery	3	1	Convey vision better, make it concise and easier to communicate How do we reach people? Change the story telling?	2
	Vehicle	3	2	Need a media/social media plan	2
Recruitment and Retention	Sourcing	3	2	Expand networks, work with other organizations so no one is competing	7
	Motivation	3	2	Share project milestones and the data, show the data in context of other data, give people a standing in the community	4
	Investment	3	2	Have follow up support, training video, recruit more to help people understand the methods	3
	Return	3	1	Communicate/visualize long term goals, google map showing other contributors	2
Scientific Contribution	Objective	3	1	Clearly define scientific research question – clear goal	1
	Quality	3	2	Need follow up support, emphasize consistency, peer reviewed data checks(quality control)	5
	Analysis	3	0	Need method on data analysis, decide what data is desired from the project	5
	Sustainability	3	1	Continuous search for funding, cross train, strategic planning	6

After evaluating the Baykeeper street litter audits, a formal improvement plan was created. To improve the street litter audit program, it is recommended that the EcoCentre clearly define a scientific research question. This will allow the long-term vision of the project to be more easily communicated to the wider public and participating volunteers. Having a well-defined scientific objective will also increase the validity of the program and the data being collected and facilitate the development of a data analysis plan.

Next, the EcoCentre would benefit from establishing a communication plan. With a proper plan in place, communication of objectives will be more regular and comprehensive. It is recommended that when the plan is in place, the EcoCentre spread information about the Baykeeper street audits and the general microplastic problem by using concise language told through a story to appeal to the public’s emotions. Additionally, harnessing and elaborating upon current news events will allow the EcoCentre to tie the Baykeeper program to real-world problems which will increase interest in the subject.

The third priority is to refine the training materials and create a training video. It is also important to recruit volunteers who are capable of training and supervising the audits. The final necessary improvement before moving forward is to create an accessible database.

This can be very simple in the beginning, but in the future, it is recommended that the EcoCentre develop an online database which shows the locations of audits and the data collected. This will enhance the motivation of volunteers.

As soon as the Baykeeper project progresses to better spread word of the project, involve participants, and keep volunteers returning, it is recommended that the EcoCentre determine how data will be analysed. This will likely involve collaborating with scientists and experts in the field of microplastic pollution to decide what type of scientific data trends will be investigated. Additionally, a brief initial quality control check should be put in place to enhance scientific rigour.

Finally, the Baykeeper street audit program would benefit from continuously increasing funding and expanding networks. Recurring applications for grants will lead to greater access to various resources, and greater resources will increase the longevity of the program. Widening the number of connections with other organisations will expand the scope of the EcoCentre and allow for networking as well as a growth in volunteer capabilities.

4.2 Discussion

In this section, we will discuss the process through which we developed our best practice rubric, the potential applications of the rubric, a guide on how to use the best practice rubric, limitations of the rubric’s use, and critiques of our rubric, assessment, and improvement plan.

4.2.1 Rubric Development Process

To make the rubric as generally applicable as possible, we decided to make it based on program design rather than outcomes. Therefore, instead of having criteria in terms of number of participants or level of data quality, we developed our criteria to address aspects of program design. In doing this, citizen science programs with vastly different resources, goals, and methods can still benefit from our rubric. While we conducted participant observation and interviews with experts, detailed notes were taken. From those notes, a list of commonly used terms that seemed to be key characteristics was created. The words were grouped into similar categories, such as Training, Recruitment, Scientific Contribution, Spreading Awareness, and Retention. Between many of these broad categories we found similarities, so we determined three broader categories or elements: Spreading Awareness, Recruitment and Retention, and Scientific Contribution.

After deciding upon the three main rubric elements, we brainstormed topics from our list of terms that would fit in each element. For example, the topics in the Spreading Awareness element were Diverse, Emotions, Goals, Hot Subject, Leveraging Events, Regular/Frequent, Story, Tailored, Values, and Vision. We then further grouped the topics into subelements. A full list of subelements and topics is located in Appendix I.

The first column of rubric descriptions that we developed was the Level 3 column. We considered the subtopics in each subelement and wrote a 1-2 sentence description of how an ideal citizen science project would address each subtopic. For example, a gap between the target and current state levels for Objective may be addressed by clearly defining and documenting the research question. We then wrote a description for each subelement in the Level 0. Level 1 and Level 2 descriptions were defined scaling the level criteria. When we completed our first draft, we discussed our rubric with Neil Blake and Fam Charko to refine the wording and subelements. We developed a supplementary document that explains in depth the criteria for each of the subelements, located in Appendix F.

4.2.2 Potential Applications

The rubric was designed to assess projects and programs that collect data to contribute to a scientific initiative through the use of volunteers and can be applied to citizen science programs not only within the EcoCentre but also outside of the EcoCentre. Although the focus of the rubric is on projects with heavy emphasis on scientific data collection, citizen science projects designed more to educate or involve volunteers can also be evaluated using the rubric. The rubric is flexible and can be used for continuous improvements through assessments of the categories and subelements.

4.2.3 Implementation Guide

To properly assess a citizen science project, a theoretical best-case rating must first be determined. Figure 6 shows the entire implementation process and should be followed when evaluating a citizen science project. Taking limitations of the project into consideration, such as resources, time, and uncontrollable outside factors, an ideal score for each subelement should be chosen. For example, if a project is addressing a topic that is not a widely recognized concern, it would be unrealistic to aim for a score of 3 in the "Content" subelement. Similarly, low-budget projects with little funding may not necessarily be able to promote awareness through many vehicles, and the best score to pursue may be a 1 in the "Vehicle" subelement. A project with little emphasis on the scientific contribution would set the target scores low in that area. After reading the various levels of each subelement, the column that best describes the conceptually perfect state of the project should be chosen as the theoretical best-case level for that subelement.

Once there is a goal level for each subelement, the current state of the project can be assessed. The row containing the description that best describes the project would be selected as the current level. If an aspect of the project can fall under multiple levels, it is recommended that the lowest level be chosen to indicate room for improvement. For example, if a project covers a relatively well-known topic, but doesn't have a clear path to a positive outcome, the project should be ranked at Level 1 instead of Level 2.

After determining both the best-case level and the current state level of the project for each subelement, the differences in the levels can be used to identify gaps and areas for improvement. For example, if the program has a best-case Level of 2 for the “Investment” subelement and the current state is at a Level 1, then this shows there is room for improvement with the time commitment, clarity of the training, or the barriers for citizen scientists to participate in the project. Identifying the differences in the best-case levels and current state levels for each of the subelements of the rubric will highlight the areas where there is room for improvements to be made.

Next, it is crucial to determine strategies to accomplish each of the desired program improvements. These strategies should then be prioritised in order of importance to the program. The improvements and their strategies can then be compiled into an improvement plan for the citizen science program to detail when and how each improvement will be accomplished. The entire program evaluation process should repeat once the initial improvements have been adapted into the program.

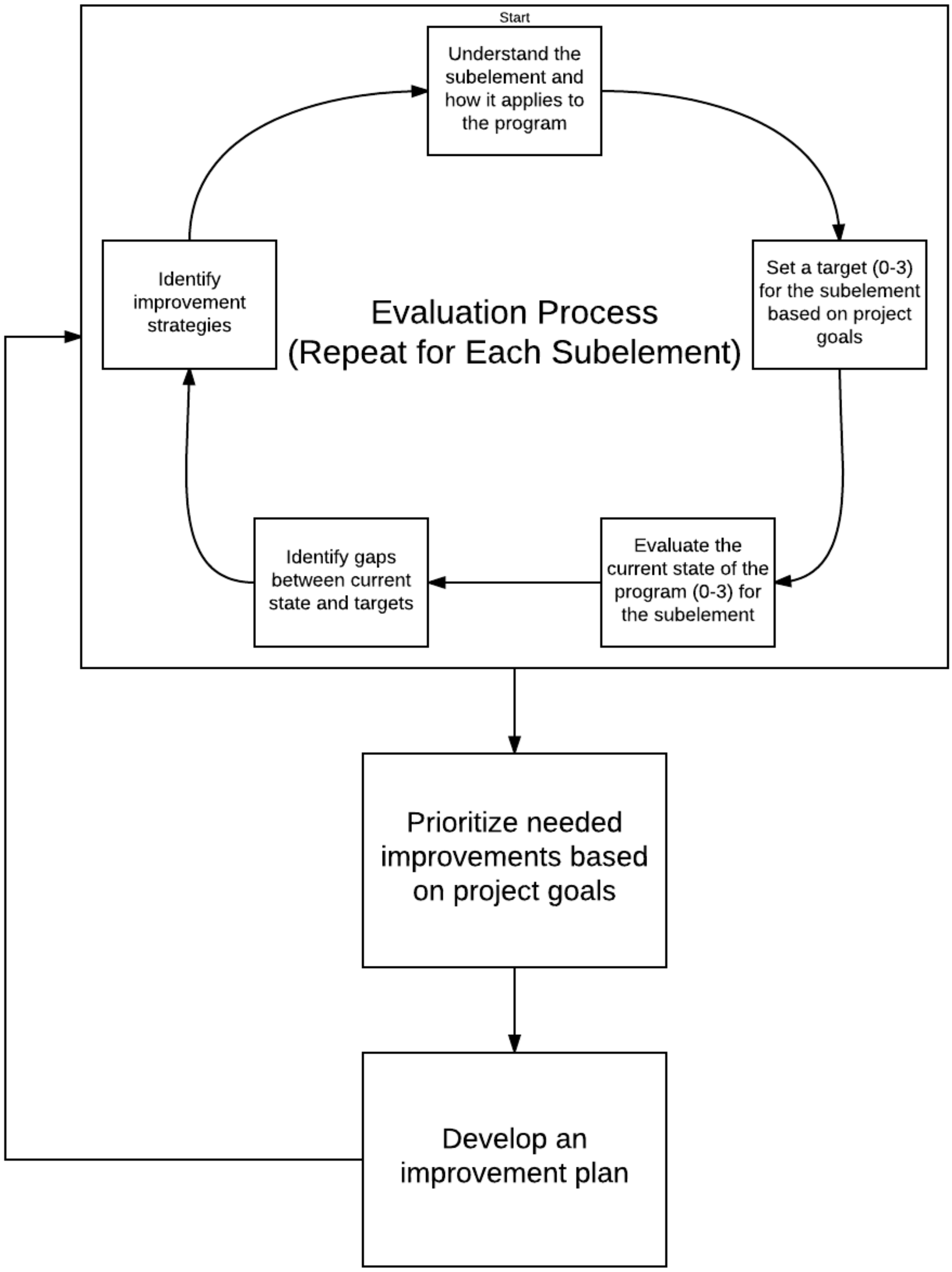


Figure 6: Implementation Process Guide

4.2.4 Evaluation of Baykeeper Audits

For the Baykeeper street audit, all target levels were set to be a Level 3, indicating that the EcoCentre staff believes that there are resources available to elevate the program to reach Level 3 in each subelement. None of the subelements are currently ranked at a Level 3, which is largely a product of the infancy of the program. Following preliminary improvements and the release of the program to the public, it is likely that the Baykeeper street audits will immediately score stronger. The evaluation indicates that there is room for improvement in every aspect of the program after implementation as well.

The Baykeeper river and creek audits are not feasible for citizen scientists to conduct with the current auditing method based on our evaluations. Litter audits on the river banks have potential safety concerns. It can be challenging to access the river bank due to overgrown vegetation and walking through this area could startle wildlife, such as snakes, living in the area which can result in harm to the participant trying to audit the area. Additionally, depending on the recent rain conditions, the river or creek might be flooded over the audit area meaning the audit area would have to either be adjusted to account for the higher water levels or the audit would need to be postponed until the water level decreases. Both adjustments would cause variations in the data collected. The current methods of river and creek audits are not practical for citizen scientists. Because the river and creek audits are not feasible with the current methods, we did not evaluate them using the rubric.

4.2.5 Critiques and Limitations

We understand that the rubric has both versatility and limitations. The usefulness of the rubric is governed by the user’s understanding and comprehension of the supporting materials and elements within the rubric. The rubric is designed to work best with small projects with a focus on scientific contribution. However, the rubric can readily be applied to a variety of programs which require choosing a target level for continuous improvement. This allows for the rubric to be tailored to projects that may not require reaching a Level 3 in each subelement. There is also value in the system outlined in this paper. Even if a citizen science project does not require the same characteristics as outlined in the rubric, it can still benefit from the continuous improvement and evaluation strategy.

4.2.6 Moving Forward

We discussed the future of our work and the Baykeeper program with the program directors, Neil Blake and Fam Charko. One immediate way they will be using our findings is in support of funding applications. They believe the evaluation and continuous improvement strategy we developed will give credibility to their process and can support funding efforts. This work will also help structure the work of the communication intern team they recently recruited. In the long term, the EcoCentre will use our work in collaboration with other organisations to demonstrate how to run a successful citizen science project.

The future of the street audit will involve making the suggested improvements and releasing it to citizen scientists. Neil has contacted Melbourne Water and enquired about monitoring the rivers and creeks near drainage areas and will pursue that avenue for river auditing. Future students from WPI will be involved in strategic planning and other EcoCentre citizen science projects.

CHAPTER 5. RECOMMENDATIONS AND CONCLUSION

Following our evaluation of the Baykeeper street and river litter audits, we were able to develop recommendations for the Port Phillip EcoCentre.

5.1 Summary of Recommendations

The following is a list of recommendations to the Port Phillip EcoCentre. Sections 5.1.1 and 5.1.2 are specific recommendations for the Baykeeper litter audits and section 5.1.3 are general recommendations to the Port Phillip EcoCentre.

5.1.1 Baykeeper Street Audit Recommendations

The following is a list of recommendations for the Baykeeper street litter audits which were developed based on our improvement plan.

1. Clearly define the scientific research question and document it
2. Develop a media/social media communication plan including:
    a. A story which connects this project to the greater problem of plastic/microplastic pollution
    b. The vision of the project clearly laid out
    c. A plan to disseminate data in an interesting way to volunteers
    d. A plan to use several different media sources to attract different participants
3. Further develop training materials
    a. Distribute the street audit training video through social media and through the Waterkeeper Alliance
4. Make the database accessible to volunteers and prospective volunteers
5. Collaborate with university scientists for peer review and data analysis strategies
6. Continuously search for funding to sustain the program
7. Continue to expand the networks

Recommendations 1-4 should be completed before the implementation of the program, but all of these recommendations are crucial to the success of the project in the future.

5.1.2 Baykeeper River and Creek Audit Recommendations

The following is a list of recommendations for the Baykeeper river and creek litter audits which were developed based on our improvement plan.

We recommend the EcoCentre look into litter trap designs that are able to collect microplastics as well as larger plastic contaminants and use these litter traps in the rivers and creeks to monitor the pollution entering the bay from these pathways.

5.1.3 General Recommendations to the Port Phillip EcoCentre

We recommend that the rubric be used periodically to re-evaluate the state of a particular citizen science program. This will ensure continuous reflection and improvement of the program. During the evaluation process, we recommend that persons from each level of the program, volunteers to high-level managers, participate in the evaluation. This will give wider perspective and observation on the current state of the program. We recommend that the Port Phillip EcoCentre keep a record of previous evaluations to provide a metric for improvement. We recommend using the rubric evaluation when seeking funding to demonstrate continuous improvement. We also recommend that the PPEC take a leadership role in the field of citizen science in the Melbourne area. In doing so, they will establish credibility in the field of citizen science, which will assist in funding and scientific credibility.

5.2 Conclusion

The goal of this project was to evaluate and improve the Baykeeper street and river litter auditing methods for functionality and usefulness when using citizen science. Following interviews and observations, our team successfully constructed an assessment rubric to evaluate design of citizen science projects. Based on our rubric, we evaluated the Baykeeper street audit and developed an improvement plan. Due to the underdeveloped nature of the river audit and safety concerns associated with it in its current state, we did not use the rubric to assess it. We instead focused on how the scientific objective could be achieved in a different manner. From our assessment, we developed an improvement plan for the EcoCentre. To initiate the implementation of the improvement plan, we created a training video for the street litter audit program. The citizen science rubric will allow for the EcoCentre to obtain more funding in the future, and can be widely used by other organisations with projects in citizen science.

References

About Baykeeper. (2017). Retrieved from https://www.bay-keeper.com/about/

Andrady, A. L. (2011). Microplastics in the Marine Environment. *Marine Pollution Bulletin, 62*(8), 1596-1605. doi:10.1016/j.marpolbul.2011.05.030

Bayas, A., Buckley, M., Ford, C., & Lawes, J. (2017). A Citizen Science Platform for Long-Term Monitoring of Microplastic Pollution in Port Phillip Bay (Undergraduate Interactive Qualifying Project No. E-project-050117-214848). Retrieved from Worcester Polytechnic Institute Electronic Projects Collection: https://web.wpi.edu/dPubs/E-project/Available/E-project-050117-214848/unrestricted/EcoCentre_Report.pdf

BirdLife Australia. (2017). Aussie Backyard Bird Count. Retrieved from https://aussiebirdcount.org.au/

Blake, N., & Charko, F. (2014). *Pilot Study of Micro-Plastics in the Maribyrnong and Yarra Rivers and Port Phillip Bay.* Victorian Government Cleaner Yarra & Bay Litter Hotspots Program.

Berg, B. L., & Lune, H. (2012). *Qualitative Research Methods for the Social Sciences* (8th ed.). Boston: Pearson.

Bonney, R., Shirk, J., Phillips, T., Wiggins, A., Ballard, H., Miller-Reshing, A., & Parrish, J. (2014). *Next Steps for Citizen Science*. New York, New York: AAAS.

Cigliano, J. A., Meyer, R., Ballard, H. L., Freitag, A., Phillips, T. B., & Wasser, A. (2015). Making Marine and Coastal Citizen Science Matter. *Ocean & Coastal Management, 115,* 77-87. doi:10.1016/j.ocecoaman.2015.06.012

Clark, J. R., Cole, M., Lindeque, P. K., Fileman, E., Blackford, J., Lewis, C., Galloway, T. S. (2016). Marine Microplastic Debris: A Targeted Plan for Understanding and Quantifying Interactions with Marine Life. *Frontiers in Ecology and the Environment, 14*(6), 317-324. doi:10.1002/fee.1297

Cole, M., Lindeque, P., Halsband, C., & Galloway, T. S. (2011). Microplastics as Contaminants in the Marine Environment: A Review. *Marine Pollution Bulletin, 62*(12), 2588-2597. doi:10.1016/j.marpolbul.2011.09.025

Dickinson, J. L., Shirk, J., Bonter, D., Bonney, R., Crain, R. L., Martin, J., Purcell, K. (2012). The Current State of Citizen Science as a Tool for Ecological Research and Public Engagement. *Frontiers in Ecology and the Environment, 10*(6), 291-297. doi:10.1890/110236

Done, T., Roelfsema, C., Harvey, A., Schuller, L., Hill, J., Schläppy, M., Loder, J. (2017). Reliability and Utility of Citizen Science Reef Monitoring Data Collected by Reef Check Australia, 2002–2015. *Marine Pollution Bulletin,* doi:10.1016/j.marpolbul.2017.01.054

The Ecohouse Vision. Retrieved from http://www.ecocentre.com/home/background

Google Maps. (2017). *Port Phillip EcoCentre*. Retrieved from https://www.google.com.au/maps/place/Port+Phillip+EcoCentre/@-

38.1598792,144.5828945,10z/data=!4m5!3m4!1s0x6ad6685e6c889829:0xde5f06ff9bbaaad7!8m2!3d-37.8699093!4d144.9823259

Gregory, Murray R. (2009). Environmental Implications of Plastic Debris in Marine Settings—Entanglement, Ingestion, Smothering, Hangers-on, Hitch-hiking and Alien Invasions. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*(1526), 2013-2025. doi:10.1098/rstb.2008.0265

Hidalgo-Ruz, V., Gutow, L., Thompson, R. C., & Thiel, M. (2012). Microplastics in the Marine Environment: A Review of the Methods used for Identification and Quantification. *Environmental Science & Technology, 46*(6), 3060. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/22321064

Jambeck, J., Geyer, R., Wilcox, C., Siegler, T., Perryman, M., Andrady, A., Law, K. (2015). Plastic Waste Inputs from Land into the Ocean. *Science, 347*(6223), 768. doi:10.1126/science.1260352

Lerner K. L. & Lerner B. W. (Eds.). The Gale Encyclopedia of Science (5th ed.). Farmington Hills, MI: Gale. Retrieved from http://libraries.state.ma.us/login?gwurl=http://link.galegroup.com/apps/doc/JIBCIC122267752/SCIC?u=mlin_c_worpoly&xid=e56629b9

Melbourne Water. (2017). Retrieved from https://www.melbournewater.com.au/

Napper, I. E., & Thompson, R. C. (2016). Release of Synthetic Microplastic Plastic Fibres from Domestic Washing Machines: Effects of Fabric Type and Washing Conditions. *Marine Pollution Bulletin, 112*(1-2), 39-45. doi:10.1016/j.marpolbul.2016.09.025

Pirc, U., Vidmar, M., Mozer, A., & Kržan, A. (2016). Emissions of Microplastic Fibers from Microfiber Fleece during Domestic Washing. *Environmental Science and Pollution Research, 23*(21), 22206-22211. doi:10.1007/s11356-016-7703-0

Ryan, P., Moore, C., van Franeker, J., & Moloney, C. (2009). Monitoring the Abundance of Plastic Debris in the Marine Environment. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 1999-2012. doi:10.1098/rstb.2008.0207

Port Phillip and Westernport Catchment Management Authority. (2012). Introduction to Waterways and Wetlands. Retrieved from http://www.ppwrcs.vic.gov.au/assets-areas/whole-region/waterways-and-wetlands-across-the-whole-region/introduction-regarding-waterways-and-wetlands-across-the-whole-region/?l1=0&l2=2&l3=0

Port Phillip Bay (2009). Australian Government Department of the Environment, Water, Heritage and the Arts. Retrieved from https://www.environment.gov.au/system/files/resources/2abc2d6b-d518-44d4-87c0-a1f2f9638a56/files/mainland-islands-port-phillip-bay.pdf

Rech, S., Macaya-Caquilpán, V., Pantoja, J. F., Rivadeneira, M. M., Kroeger Campodónico, C., & Thiel, M. (2015). *S10661 015 4473 y*

State Government of Victoria. (2013). Bay and Catchments Retrieved from https://yarraandbay.vic.gov.au/assets/bay-and-catchments

Solomon, O., & Palanisami, T. (2016). Microplastics in the Marine Environment: Current

Status, Assessment Methodologies, Impacts and Solutions. *Journal of Pollution Effects & Control, 4*(2) doi:10.4172/2375-4397.1000161

Van Cauwenberghe, L., Devriese, L., Galgani, F., Robbens, J., & Janssen, C. R. (2015). *Microplastics in Sediments: A Review of Techniques, Occurrence and Effects* doi://dx.doi.org/10.1016/j.marenvres.2015.06.007

Vann-Sander, S., Clifton, J., & Harvey, E. (2016). *Can Citizen Science Work? Perceptions of the Role and Utility of Citizen Science in a Marine Policy and Management Context* doi://dx.doi.org/10.1016/j.marpol.2016.06.026

Ward, K., editor. (2014). *Researching the City*. Thousand Oaks, California; London: SAGE.

Waterkeeper Alliance. (2017). About us. Retrieved from http://waterkeeper.org/about/

What is a Benthic Habitat Map? (2017). Retrieved from https://oceanservice.noaa.gov/facts/benthic.html

Wright, S. L., Thompson, R. C., & Galloway, T. S. (2013). The Physical Impacts of Microplastics on Marine Organisms: A Review. *Environmental Pollution (Barking, Essex: 1987), 178*, 483-492. doi:10.1016/j.envpol.2013.02.031

APPENDIX A: INTERVIEWEE CONTACT INFORMATION

Kade Mills	Email: kade@vnpa.org.au Phone: 03 9341 6519
Ray Lewis, OAM	Email: ray@lewisfamily.com.au
David Mossop	Email: david.mossop@epa.vic.gov.au Phone: 03 8458 2369
Ross and Ramona Headifen	Email: ross@headifen.com; ramona@headifen.com Phone: 04 1287 6154; 04 3267 8223
Fam Charko	Email: fam@ecocentre.com Phone: 03 9534 0670
April Seymore	Email: april@ecocentre.com
Donna Sheil	Email: donna.shiel@sustainability.vic.gov.au Phone: 03 8626 8761
Nicole Kowalczyk	Email: bayproject@yarrariver.org.au Phone: 04 0385 6528
Jill Sokol	Email: 3184-1@loveourstreet.com.au Phone: 04 0398 7921
Neil Blake, OAM	Email: baykeeper@ecocentre.com Phone: 03 9534 0413

APPENDIX B: CITIZEN SCIENCE EXPERT INTERVIEW QUESTIONS

How do you use citizen science?

What should you do/not do in a citizen science project? In terms of:
- Outreach
- Methods
- Data collection
- Data analysis
- Recruitment
- Education
- Training
- Resources
- Statistical rigour

How can this be translated to microplastics and the PPEC's methods?

What are some previous projects that you have worked on?

Are there any current projects that we can observe?

What are some citizen science projects you have participated in as a citizen scientist?

What projects in the area have caused significant community change?

How can the government agencies be used to spread awareness/educate?

What are the limitations of the government?

How can continuous improvement be ensured without making it difficult for citizen scientists?

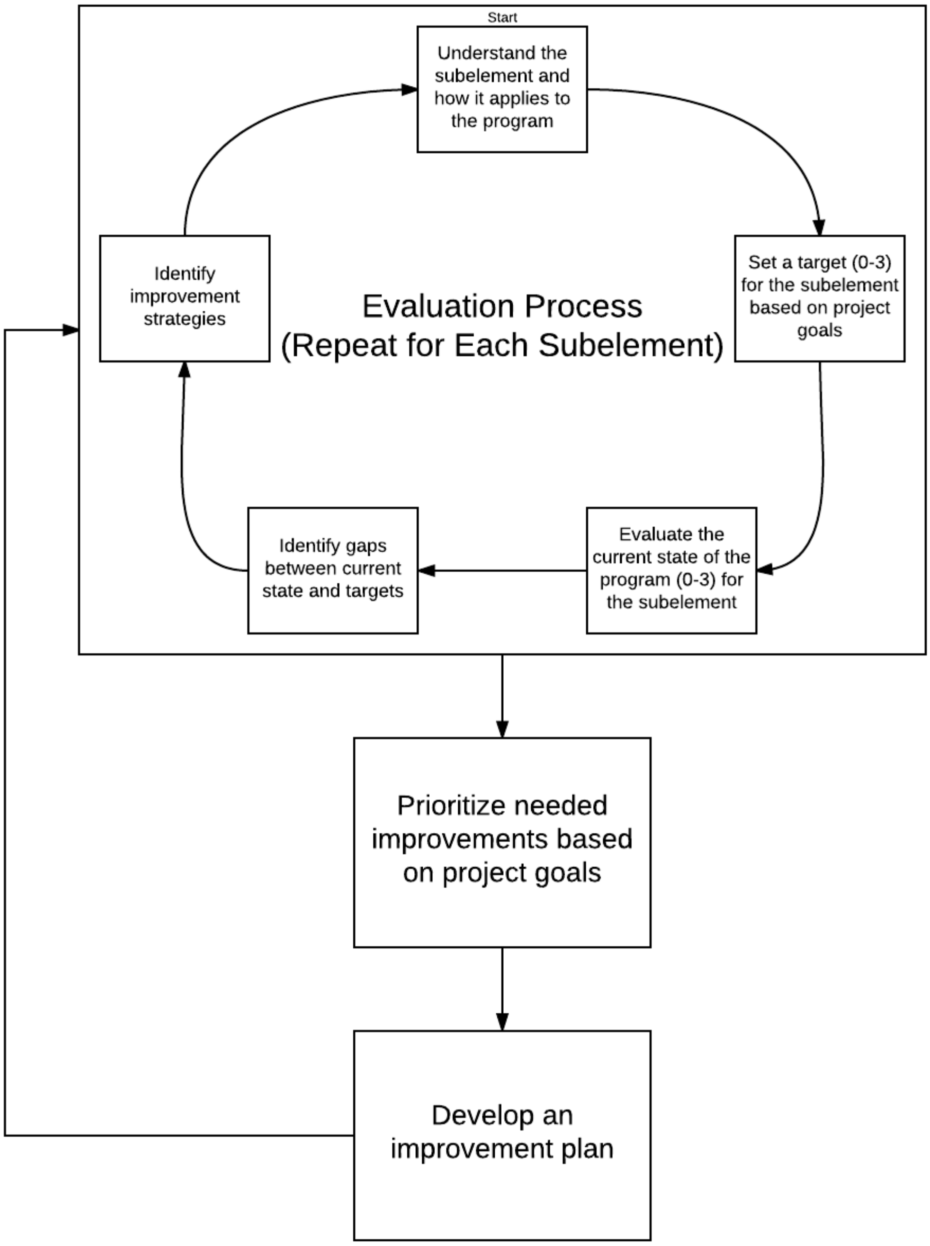
APPENDIX C: SUBELEMENT CRITERIA

<table>
<tr><th>Element</th><th>Subelement</th><th>Key Questions to Ask About the Program</th></tr>
<tr><td rowspan="3">Spreading Awareness</td><td>Content</td><td>What is actually said to volunteers and the wider community?
How well-known is the topic?
Does the project show a path to a positive outcome?
If applicable, are any news events regarding the topic leveraged to promote the project?</td></tr>
<tr><td>Delivery</td><td>How is the content delivered? (public/wider community)
Is the vision of the project conveyed?
Does the information provided tell a story?
Is the content clear?
Does this information play to the emotions and values of participants and the wider community?</td></tr>
<tr><td>Vehicle</td><td>Where and when is the information delivered?
Is information periodic?
What media is it delivered through?
Is the message tailored to the demographics using each medium?</td></tr>
<tr><td rowspan="4">Recruitment and Retention</td><td>Sourcing</td><td>Where do the volunteers come from?
Do they come from a number of different sources?
Are these sources diverse e.g. (organisations, schools, unaffiliated etc.)?
Do these sources provide opportunities for networking?</td></tr>
<tr><td>Motivation</td><td>How does the project motivate participants?
Is there a community among participants?
Do the participants share values, goals, and a vision for the project?
Do participants recruit other participants?
Are the participants aware of the research question?
Are they committed to answering the research question?</td></tr>
<tr><td>Investment</td><td>How much investment does participation require of the participants?
How much time commitment does it require?
How much effort does it require?
How long does training take?
Is there any follow up?
Are the methods simple?
Are there any barriers to entry e.g. travel, background knowledge etc.?</td></tr>
<tr><td>Return</td><td>What do participants get out of participating?
Are there immediate results?
Are they tangible or easily visible (not abstract)?
Is long term data accessible?
Is there any tangible reward e.g. T-shirts, food, etc.?
Is there a lot of social interaction?
Is there reciprocity between your organisation and participants' organisations?</td></tr>
</table>

Scientific Contribution	Objective	• How is the scientific objective defined? ○ Is the objective well defined? ○ Does it answer the research question? ○ Does it address limitations involved? ○ Do the methods produce data which fulfill this objective?
	Quality	• How is the quality controlled? ○ Are the methods standardised? ○ Is the training standardised? ○ Are methods simple and clear? ○ Is the training simple and clear? ○ Does the training emphasise the need for scientific rigor? ○ Is there a preliminary quality control in place e.g. an acceptable range of values?
	Analysis	• How is the data analysed? ○ Is data analysed with reference to a baseline or outside benchmark? ○ Is it analysed in a standard way across the life of the project? ○ Is it analysed by experts? ○ Is data quality analysed? ○ Is data quality accounted for in analysis?
	Sustainability	• How is the project sustained? ○ Are findings disseminated to the public? ○ Are they disseminated to the scientific community? ○ Are they disseminated transparently? ○ Is feedback from the public and scientific community considered and incorporated as appropriate? ○ Are individual managerial project roles simple? ○ Are personnel cross-trained? ○ Are there resources available to sustain the project?

APPENDIX D: IMPLEMENTATION GUIDE

Rubric Implementation Cycle



APPENDIX E: CITIZEN SCIENCE PROGRAM EVALUATION WORKSHEET

Element	Subelement	Target Level	Current Level	Ways to Improve	Priority Ranking
Spreading Awareness	Content				
	Delivery				
	Vehicle				
Recruitment and Retention	Sourcing				
	Motivation				
	Investment				
	Return				
Scientific Contribution	Objective				
	Quality				
	Analysis				
	Sustainability				

APPENDIX F: CITIZEN SCIENCE DISCUSSION GUIDE

Why are you participating in this project/training?

Do you think there is room for improvements in the program? If yes, please explain.

Do you think there is room for improvements in the training methods of the program? If yes, please explain.

Have you ever conducted volunteer research on a different project? If you have conducted volunteer research on a different project, what was the name of the project and how did it compare to this project?

What keeps you coming back to participate in this project?

What greater cause do you feel you are contributing to?

How old are you?

Do you have a good understanding of the purpose of the survey?

Would other people you know be interested in this activity?

Is the time commitment to complete each session suitable for you?

How many times a year would you be happy to commit to ongoing project?

What are the key features of the project that increase your satisfaction in being involved?

Can you identify things that could increase your satisfaction if included in the project/method?

APPENDIX G: CITIZEN SCIENCE EXPERT INTERVIEW TAKEAWAYS

Kade Mills

- Outreach
  - Conferences
  - Find key people
  - Social media
  - Stories
  - Swag/make people feel special (part of a group)
- Retention
  - Feedback
  - Acknowledgement
  - Shared vision
  - Goals
  - Updates
- Training
  - Keep it simple
  - Know what you're doing
  - Engaging video
  - Visuals/visual guides
- General
  - Replaceability
  - Ask for help
  - Find smart people
  - Know your limits
  - It's ok to fail/scrap shitty projects
  - Demographic tailoring/age gaps
  - Share everything
  - Don't underestimate people
  - Pilot programs
  - Delegate
- Data quality
  - Ask for experience level
  - Identify outliers

Ray Lewis

- General
  - Tailor information
  - Delegate
  - Replaceability

    - Value suggestions
- Outreach
    - Be clever/fun
    - Make people understand value
    - Repetition
    - Feedback
    - Empower people with a title (citizen scientist)/photograph people
    - Find people that care
    - Be open to all organisations
    - Use events to spread news
- Training
    - Videos require commitment
    - Teach people first hand
    - Ask questions to check understanding
    - Visual guide
- Communication
    - Limit number of people that can contact everyone
    - Be transparent
- Data quality
    - Standardise
    - Leave data analysis to scientists

David Mossop
- Outreach
    - Empower people
    - Utilise knowledge/listen to what they have to say
    - Regular feedback/monthly check-ins
    - Show that data is being used
    - Artwork
    - Pics/videos (be creative)
    - Inspire different demographics
    - Feedback (before/during/after)
- Training
    - Good first-hand training
    - Make it simple/idiot proof
    - Quick
    - Tailor materials to demographic
    - Make sure anyone can train
    - Pilot exercises
    - Laminated/robust training gear
- Data quality
    - Have a research question
    - Have restrictions on input/know outliers

- Use pen and paper rather than mobile
    - Standards in collection (international)
    - Have experts verify
    - Periodic data collection
    - Verify people know what they're doing
- General
    - Be realistic
    - Keep it simple
    - Phases/pilots for continuous improvement
    - Get expert opinions
    - Replaceability
    - Know your limits
- Communication
    - Social media
    - Email
    - Communicate that things can possibly change/explain why
    - Ask people what they want
    - Tell community story

Ramona and Ross Headifen

- Data quality
    - Accounted for outside factors
    - Periodic data collection
    - Simple data sheet
- Training
    - Simple method
- Communication
    - Publish data
    - Influence policy

Fam Charko

- General
    - Safety
    - Using citizen science to educate vs. for science
    - Make it sexy
    - Pilot
- Data quality
    - Know your limits
    - Grab previously recorded data if you want
    - Data relates to research question
    - Monthly data collection
    - Scientists analyse
- Training

    - Consistent
    - Tailoring to demographic
- Outreach
    - Flood (mass outreach, all routes)
    - Acknowledgement/celebrate
    - Incentives
    - Networks
    - Social media/email
- Communication
    - Make it fun
    - Speak to people's values
    - Share results

April Seymore

- General
    - Mass collaboration
    - Prioritise efforts
- Outreach
    - Build awareness
    - Advertise/utilise media
    - Share a story/be dramatic
    - T-shirts/name tags/uniforms/identify as a tribe
    - Bring back the satisfaction (give feedback)
    - Present at schools/conferences
- Training
    - Keep it simple
    - Provide materials needed to do the task
    - Age appropriate
    - Be able to teach after learning
    - Online training is a nope/in person is best
    - Replaceability
- Communication
    - Newsletter
    - Make personal connection
    - Use anger/passion/emotions
    - Annual meetings - let people tell stories
- Data quality
    - Tie data to something physical

Donna Sheil

- Outreach
    - Use existing networks
    - Acknowledgements

    - Create sense of community
    - Tailor to demographics
- New categories
    - Time
    - Money/resources
- Communication
    - Feedback should be public knowledge/inform future projects
    - Share progress
    - Tell a story
- Data quality
    - Simplify analysis
    - Publish - share everything
    - Multiple options to record
    - Know capabilities
- General
    - Long-term is difficult
    - Make everything efficient
    - Realistic expectations
- Training
    - Face to face

Nicole Kowalczyk

- General
    - Tailor to demographics/group size
    - Safety
    - Make it relatable
    - Know when it's for education and for science
- Training
    - Simplify
    - Accurate diagrams
    - Less colour
    - Video - cover all bases
- Outreach
    - People work with knowledge that data is used
    -
- Data quality
    - Don't count after
    - Simple data = more complete
    - Can get environmental data after the fact
- Communication
    - Keep people in the loop
    - Communicate goals
    - Story of litter

Kylie Andrews

- Outreach
  - Engage people
  - Tailor to all demographics
  - Get classes involved
  - Have a broadcasting network at your disposal (helpful)
- Retention
  - Make people feel special
  - Maximise communication and engagement with volunteers
  - Don’t underestimate the power of giving something back
  - Feedback
  - If people are interested then they’ll make time
- Training
  - Make training super simple/low barrier to entry
- General
  - Pilot programs
  - People want to give back
  - Periodic big number feedback to keep people in the loop
  - Get smart people involved
- Data Quality
  - Work towards scientific goal
  - Have lots of people do it

Jill Sokol

- Outreach
  - Community bond
  - Data not as important to people
  - Get people who do other local projects
  - Use art to get people's attention
  - Engage with schools
- Retention
  - Social aspect
  - Keep the events local/close to home
  - Immediate reward/results
- Training
  - Have experienced people train new members
  - Keep it simple
- General
  - Count data after
  - Give big number feedback (cigarette butts/drink bottles)
  - People don’t want to do frequency
  - Safety is important

    - Be able to adapt to different needs/barriers
    - Co-manager
- Data Quality
    - Standardisation

APPENDIX H: DETAILED RUBRIC

Element	Subelement	Level 0	Level 1	Level 2	Level 3
Spreading Awareness	Content	The project covers an obscure topic and shows no path to positive outcomes. The project misses vital opportunities to leverage current or past events.	The project covers a relatively obscure topic. The goals of the project are vaguely defined with some path to a positive outcome.	The project covers a relatively well-known topic and is able to show a somewhat clear path to a positive outcome. Occasionally leverages events to further interest in project.	The project relates clearly to a popular subject and its goals show a clear path to a positive outcome. The project is able to leverage events local and abroad, as appropriate, in a meaningful and effective way.
	Delivery	The audience is not informed of the project vision, there is no accompanying story to be inspired from, and the project does not align with the audience's values.	Some of the audience is informed about some of the project vision, there is a small accompanying story to be inspired from, and the project aligns with some of the audience's values.	Most of the audience is informed about most of the project vision, there is an accompanying story to be inspired from, and the project aligns with most of the audience's values.	The purpose and long-term vision of the project is clearly laid out to the whole audience with a story which inspires interest and emotional response by aligning with the audience's values.
	Vehicle	Information is delivered through very limited outlets. Communication is very sparse and irregular. Information is not tailored to different demographics or only targets a specific audience.	Information is delivered through limited outlets. Communication is limited and irregular. Information is sometimes tailored to different demographics.	Information is delivered somewhat regularly through several vehicles and is often tailored to the demographic using each vehicle.	Information is delivered periodically through diverse vehicles including social media, printed news, email, conferences/speeches, and newsletters, and is tailored to the demographic using each vehicle.

Element	Subelement	Level 0	Level 1	Level 2	Level 3
Recruitment/Retention	Sourcing	Volunteers all come from a similar demographic and random inconsistent sources. The volunteers do not come from organisations/networks.	Volunteers come from similar demographics and a few inconsistent sources. Some volunteers come from organisations/networks.	Volunteers come from various demographics and a few consistent sources. Most volunteers come from organisations/networks.	Volunteers come from a diverse pool of consistent sources and come from organisations/networks.
	Motivation	This project does not create a sense of community among participants and does not facilitate the sharing of values, goals, and a vision. Participants are not engaged in answering the research question.	This project sometimes creates a small sense of community among participants and sometimes facilitates the sharing of values, goals, and a vision. Participants are sometimes engaged in answering the research question.	This project often creates a sense of community among participants and allows for the sharing of values, goals, and a vision. Participants are usually engaged in answering the research question.	The project creates a community among participants, sharing values, goals, and a vision which leads to repeated participation and effortless recruitment. Participants are aware of the research question and committed to answering it.
	Investment	There is a large time commitment and effort required. Training is long and complex and lacks follow up support. There is a high barrier to entry.	There is a large time commitment and effort required. Training is somewhat long and complex and there is limited follow up support. There is a significant barrier to entry.	There is a moderate time commitment and effort requirement. Training is mostly basic and easy to follow and follow up support is provided. There is a low barrier to entry.	The project requires minimal time commitment and is not effort intensive. Training is brief, there is consistent follow up support and methods are simple. There is no barrier to entry.
	Return	The results for the project are not immediately tangible and the data is not accessible to show progress. There is no tangible reward or cross-organisational reciprocity and very limited social interaction.	The results for the project are sometimes tangible and the data is not easily accessible to show progress. There is little tangible reward, social interaction, and cross-organisational reciprocity.	Some results for the project are immediately tangible and most of the data is easily accessible to show progress. There is significant tangible reward, social interaction, and cross-organisational reciprocity.	The project produces immediately tangible results as well as accessible data which provides long term progress visibility. There is a high level of tangible reward, social interaction, and cross-organisational reciprocity.

Element	Subelement	Level 0	Level 1	Level 2	Level 3
Scientific Contribution	Objective	The scientific objective of this project is undefined and does not align with research questions and does not account for limitations. Methods don't produce data that fulfills this objective.	The scientific objective of this project is somewhat defined and partly aligns with the research question and some limitations are accounted for. Methods produce some data that fulfil the objective.	The scientific objective of the project is defined based on the research questions and most of the limitations involved. Methods produce data which mostly fulfil this objective.	The scientific objective of the project is well defined based on the research questions and any and all limitations involved. Methods produce data which completely fulfills this objective.
	Quality	Methods and training are complex, difficult to understand, and not regulated for standardisation. No initial quality control is conducted. Training materials do not promote a deeper understanding of the project and don't emphasise scientific rigor.	Methods and training can at times be complex, difficult to understand, and not completely regulated for standardisation. Very little initial quality control is conducted. Training materials sometimes promote a deeper understanding of the project and have minimal emphasis on scientific rigor.	Methods, training, and accompanying materials are often simple, clear, and standardised. Some preliminary quality control protocol is in place. Training materials frequently promote a deeper understanding of the project, methods and have an emphasis on the need for scientific rigor.	Methods, training, and accompanying materials are simple, clear, and standardised. A preliminary quality control protocol is in place. Training materials always promote deeper understanding of the project, methods, and have a large emphasis on the need for scientific rigor.
	Analysis	There is no benchmark to reference data against, and data is not analysed in a standard way. Data quality is not accounted for.	Data is sometimes analysed in a standard way. Data quality is sometimes accounted for. The baseline or outside benchmark is not always accurate.	Data is most often analysed in a standard way. Data quality is usually accounted for. The baseline or outside benchmark is mostly accurate.	Data is analysed with reference to a preliminary baseline or outside benchmark in a standarised way by experts. Data quality is analysed and accounted for.
	Sustainability	Public has no knowledge of the findings and there is no opportunity to provide feedback. Roles are complex and crucial personel are not replaceable. Project has no access to ongoing resources.	Public is aware of some of the findings and are provided an opportunity to give feedback. Some roles are complex and there is minimal cross training. Project has limited access to ongoing resources.	Public has knowledge of most of the findings and feedback may be taken into consideration when making improvements. Few roles are complex and there is some cross training of crucial individuals. Project has sufficient acccess to ongoing resources.	Findings are transparently disseminated to the public and the scientific community and feedback is incorporated. Individual roles are simple and crucial personnel are cross-trained to ensure replaceability. The project has access to a surplus of ongoing resources.

APPENDIX I: RUBRIC SUBELEMENTS AND TOPICS THEREIN

Spreading Awareness

- Content
  - Hot subject
  - Goals
  - Leveraging events
- Delivery
  - Story
  - Emotions
  - Values
  - Vision
- Vehicle
  - Diverse
  - Tailored
  - Regular/frequent

Recruitment and Retention

- Sourcing
  - Diversity
  - Consistency
  - Networking
- Motivation
  - Vision
  - Hot subject
  - Emotions
  - Community
  - Values
- Investment
  - Time
  - Effort
  - Training
- Return
  - Immediate satisfaction
  - Long-term satisfaction
  - Acknowledgement

Scientific Contribution

- Objective
  - Research question
  - Limitations
  - Goals

- Quality
    - Methodology
    - Standardisation
    - Training
- Analysis
    - Benchmark
    - Standardisation
    - Scientists
- Sustainability
    - Feedback
    - Replaceability
    - Communication/dissemination
    - Continuous improvement