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Comparison of marine debris data collected by researchers and citizen scientist: Is citizen science data worth the effort?

Tonya van der Velde [a,*], David A. Milton [a], T.J. Lawson [b], Chris Wilcox [c], Matt Lansdell [c], Geraldine Davis [d], Genevieve Perkins, Britta Denise Hardesty [c]

[a] CSIRO Oceans and Atmosphere, PO Box 2583, Brisbane, Qld. 4001, Australia
[b] CSIRO Land and Water, PO Box 312, Clayton South, Vic. 3150, Australia
[c] CSIRO Oceans and Atmosphere, PO Box 1538, Hobart, Tas. 7000, Australia
[d] Envirodot International, PO Box 452, Flemington, Vic. 3031, Australia
[e] Geomatics and Landscape Ecology Research Laboratory (GLEL), Department of Biology, Carleton University, Ottawa, ON, Canada

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ABSTRACT

As part of a national research program studying the sources, distribution, and effects of litter entering the ocean, we established a national citizen science program engaging nearly 7000 primary and secondary students, teachers and corporate participants in collecting marine debris data around Australia's coastline. Citizen scientists undertook a one-day training program, which addressed data collection skills and academic topics in the national science curriculum. A subset of teachers and corporate sponsor staff participated in an intensive multi-day training program with researchers before venturing into the field.

Data collected by citizen scientists were compared with data collected by researchers at nearby locations. We found the citizen science data were of equivalent quality to those collected by researchers, but there were differences among students. Primary school students detected more debris than did older secondary students. Students detected small items (<1 cm^2), and were as accurate as researchers in identifying debris type and size categories. However, sampling approach was important — students detected more debris during quadrat searches than during strip transects. Comparing researcher effort to volunteer-collected data, citizen scientists were often more efficient (per m^2) than researchers at collecting marine debris, but the results varied among methods. Researchers made more surveys within a given day (0.8 surveys/person-day). However, participants of one day programs working with secondary students or adults were nearly as efficient (0.6 surveys/person-day). This study shows that engaging with citizen scientists can broaden the coverage and increase the sampling power of coastal litter and other ecological survey assessments without compromising the data.

1. Introduction

Public participation in scientific research (citizen science), has long been used to tackle research questions that would otherwise not have been addressed due to lack of resources, time or geography (Cooper et al., 2007; Couvet et al., 2008; Dickinson et al., 2010; Irwin, 2001, Silvertown, 2009). As early as the 17th century, experts recruited non-experts to contribute to natural history observations (Greenwood, 2007). Public participation in collecting scientific data has continued to grow (Miller-Rushing et al., 2012). This growth has been due to several factors, but particularly the development of technical tools for disseminating information about projects, as well as interacting with and gathering data from the public. The growth of citizen science also stems from the increasing realization among researchers that the public represent a potentially low-cost source of labor, skills, computational power and even finance (Silvertown, 2009). Research funders such as the National Science Foundation in the USA and the Natural Environment Research Council in the UK now require every grant holder to undertake science outreach as part of funded projects (Silvertown, 2009). This outreach engenders accountability and enables interested persons to potentially participate in the data collection (Silvertown, 2009).

Citizen science projects can involve volunteer participants from school-aged children to adults. Participants may be involved in a variety of roles including study design, data collection, processing and analysis, and dissemination of information to the broader community (Tulloch et al., 2013; Theobald et al., 2015). Citizen scientists participate in projects ranging from astronomy to air quality and from population ecology to

* Corresponding author.
E-mail address: tonya.vandervelde@csiro.au (T. van der Velde).

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biology (Greenwood, 2007, Dickinson et al., 2010, Tregidgo et al., 2013). One long term example of the value of citizen scientists is with bird monitoring. Volunteer engagement goes back as far as 1749 in Europe (Greenwood, 2007) with volunteer programs increasing the global knowledge of population changes in birds in many regions (Niven et al., 2004; Bonter and Hochachka, 2003; Vandenbosch, 2000) and with opportunities to apply this knowledge to achieve conservation outcomes. Astronomy has the largest participation rate by citizen scientists, with volunteers discovering numerous new stars and sky objects (Dickinson et al., 2010). This citizen scientist engagement has enabled collection of data beyond the normal scope of a conventional research project by greatly increasing the observation capacity available. Increasingly, citizen scientists are contributing to our understanding of large-scale environmental or conservation problems. In this study, we distinguish between paid, trained scientific staff, unpaid and untrained citizen scientists, and citizen scientists who are trained by paid scientific staff. However, as many researchers question the accuracy and precision of citizen science-collected data (Forrester et al., 2015, Crall et al., 2010, Hunter et al., 2013), validation of these data is critical (Boudreau and Yan, 2004). There are many studies that compare citizen scientist collected data and data collected by paid researchers (Finn et al., 2010; Gillett et al., 2012; Lovell et al., 2009). Typically, however, studies do not evaluate the type of training and its effectiveness. Suitably trained citizen scientists may have great potential to contribute valuable data on widespread environmental issues such as marine debris.

Marine debris has been identified as an increasingly important global environmental issue, alongside other key challenges including climate change, ocean acidification and loss of biodiversity (Sutherland et al., 2010). It is estimated that more than 8.4 million tonnes of plastic waste enters our oceans annually from land based sources (Jambeck et al., 2015). Density estimates are as high as 588,000 pieces of plastic per km^2 in the oceans (Law et al., 2010). The impacts of this threat on biodiversity are both broad and deep. Marine debris has been reported to have direct impacts on invertebrates, fish, amphibians, birds, reptiles, and mammals (Good et al., 2010), interacting with nearly 700 marine species at last count (Gall and Thompson, 2015) and potentially resulting in significant population level impacts on widespread or threatened marine taxa (Wilcox et al., 2015).

These impacts are known to be a significant threat to the persistence of several threatened or endangered marine species and are likely to be affecting many others. For example, up to 40,000 fur seals die each year by entanglement in debris (Derraik, 2002) and entanglement and ingestion are purportedly major causes of population decline for many marine mammals (Gall and Thompson, 2015). Similarly, it is estimated that between 5000 and 15,000 turtles are entangled each year by derelict fishing gear washing ashore in northern Australia alone (Wilcox et al., 2015) and globally approximately 1/3 of all turtles have ingested plastic debris (Schuyler et al., 2014). These impacts are likely to intensify, as plastic production is expanding exponentially (Plastics Europe, 2013).

The Commonwealth Scientific and Industrial Research Organisation's (CSIRO) National Marine Debris program was established to quantify the amount and types of litter that enter the marine environment and the potential impacts this litter may have on Australian wildlife. The project integrated field, modelling, genetic and biochemical marker approaches to understand the impact of marine debris on fauna at the national scale. One of the critical aspects of this program is engagement with school groups and other citizen scientist participants. This engagement had two foci. The first was to promote science education and learning through a timely and relevant topic, as the marine debris issue fits in well with mathematics, chemistry, physics, biology, oceanography and other parts of the national curriculum. Furthermore, the topic resonates with Australia's largely coastal population and the issue is engaging for students and the broader public. The second focus was to collaborate with citizen scientists on data collection, using the opportunity to train participants in the process to increase the pool of contributors to scientific data on coastal litter and marine debris.

Here, we investigated the quality of data collected by citizen science students and adults and compared that data to data collected by paid researchers. We focused on assessing the composition, distribution and abundance of marine debris from coastal litter surveys around Australia. We concentrated on comparing the marine debris data obtained from trained citizen scientists with that from paid researchers. This allowed us to evaluate the effectiveness (in terms of time) of including citizen science as a component of a national scientific investigation. Specifically we addressed three questions: 1) Are data collected by citizen scientists of similar quality to those collected by paid researchers; 2) Does investment in training citizen scientists, above a basic level, improve the quality of their data; and 3) From a return-on-investment perspective, can involving citizen scientists increase the sampling power of scientific projects in comparison with using only paid researchers?

2. Materials and methods

2.1. Researcher surveys

2.1.1. Site selection

The research team spent an intensive ten-day training period to trial methodologies, data collection approaches and to ensure consistency in data collection as well as best-practices for recording, detecting and reporting of data prior to initiation of research activities. We sampled debris at randomly selected coastal sites, located approximately every 100 km along the Australian coastline, except where access was prohibited (Fig. 1; see Hardesty et al., 2016).

Coastal litter surveys applied a 2 m wide strip transect approach with surveys running perpendicular from the water's edge and continuing two meters into the continuous terrestrial vegetation. A minimum of three and maximum of 6 transects were made at each site, depending on whether litter was detected in the first three transects and substrate type(s) at each site (Appendix A). Transects were located a minimum of 50 m from the access point and from each other, stratified across the substrate types where multiple substrate types occurred at a single site (sand, boulder, mangrove, etc.; see detail in Hardesty et al., 2016).

2.1.2. Data collected

We recorded the GPS location of the access point, date, name of observer(s), weather conditions, wind speed and direction, a count of people present (excluding surveyors) and time of day. For each transect we recorded the start and end times and locations and the length of transect. To account for factors that may affect debris deposition and retention, we also recorded the exposure, shape, aspect, substrate, colour, gradient, location of the dominant debris line, and the backshore type for each transect (Appendix A). To consider the potential contribution of land-based debris sources we determined the population within 5 km of each site, the population within 50 km of each site and the distance from the access point to the nearest road.

Each two metre wide strip transect was surveyed by two observers side by side, recording all litter detected from standing position within a one metre wide swath. The first item encountered within each of ten equal distance length classes along the transect line in addition to material type and colour, size was recorded based upon doubling size classes from <1 cm^2, 2 cm^2, 4 cm^2, 8 cm^2, 16 cm^2 and >16 cm^2. This subset of items was chosen for sampling efficiency as some transects had hundreds of items. Where feasible, litter was collected and removed.

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