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Citizen science: recruiting residents for studies of tagged urban wildlife

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Abstract. The human residents of cities represent a largely untapped and potentially vast source of information about urban wildlife. One simple and scientifically valuable contribution involves the reporting of sightings of tagged animals, but even in urban areas, such reports are relatively rare. We draw on two case studies of conspicuously tagged and iconic animals to consider human reactions to wildlife tags, and how these influence the likelihood of unsolicited reports. We evaluate potential strategies for increasing participation from this pool of potential citizen scientists and maximising the reliability of these contributions. In both studies, public reports contributed substantial and largely accurate data. We conclude that such reports are often of unique value, and that common sources of reporting error can be minimised by careful tag design and clear advice to participants. Effective information campaigns can have unexpected effects on reporting rates, but in general, communication is crucial to raising awareness and encouraging public involvement. New interactive web-based tools have the potential to dramatically increase public accessibility to information and encourage involvement by providing instant feedback, access to research updates, and encouraging the formation of clusters of citizen scientists.

Introduction

In the late 1980s, Kim Lowe, then coordinator of the Australian Bird and Bat Banding Scheme (ABBBS), was curious to know how often members of the public noticed and bothered to report finding banded birds (Lowe 1991). In an unconventional experiment, he traversed suburbs of Canberra, Melbourne and Sydney during the night, depositing carcasses of leg-banded birds in obvious places such as on doorsteps, or near bus stops and letterboxes. The metal leg bands, though small, contained printed instructions requesting that the finder mail the band with a report to the ABBBS. On average, barely 10% of bands were returned (Lowe 1991), suggesting that urban residents were either unobservant, uninterested, or perhaps even repulsed by the unexpected sight of a dead bird.

Lowe's study raises interesting questions about the utility of citizen science – recruiting members of the public into scientific study. Urban wildlife studies are burgeoning (Miller and Hobbs 2002; DeStefano and DeGraff 2003; Garden *et al*. 2006) and the human residents of cities represent a resource of potentially tremendous reach and value to scientists. However, studies such as Lowe's paint a discouraging picture of the prospects for engaging citizens in science.

Although the term 'citizen science' has been in use only since the 1990s, scientific studies incorporating data collected by non-professionals have a much longer history (Cohn 2008; Silvertown 2009; Mayer 2010). Once almost exclusively focussed on birds, the diversity of citizen science projects in the last decade is impressive: from monitoring of coliform bacteria in waterways (Au *et al*. 2000), to surveys of fauna and flora ranging from stands of trees (Galloway *et al*. 2006), to invasive crabs (Delaney *et al*. 2008), butterflies on migration (Howard and Davis 2009) and mammals on roadways (Lee *et al*. 2006).

Enlisting members of the public to contribute to data collection offers several well documented benefits (Cohn 2008; Bonney *et al*. 2009; Silvertown 2009). Many biologically interesting problems involve questions at large geographic scales, requiring human resources of a magnitude well beyond the means of most research teams and grants. Citizen scientists volunteer their time and thus represent a free, often well-educated, and potentially abundant, human resource. Involvement in research projects is also a potent way to increase public awareness of, and engagement with, conservation problems.

Studies using marked animals have benefited from citizen reports in a wide range of species, from horseshoe crabs (*Limulus polyphemus*; Smith *et al*. 2006) to common seals (*Phoca vituline*; Hewer 1955; Bonner and Witthames 1974). Bird researchers often draw heavily on public reports of marked birds, as seen in studies of waterfowl migration in Europe (e.g. Nilsson and Persson 1991; Madsen 2001) and North America (e.g. Craven and Rusch 1983; Ely *et al*. 1997). In the case of game species, hunters contribute to research by reporting marked animals that have been shot (e.g. Trost *et al*. 1980; Alisauskas *et al*. 2006). In the main, however, these public contributions involve coordinated exercises with trained volunteers, rather than unsolicited reports such as those sought by Lowe.

In this paper, we consider the advantages and potential pitfalls of unsolicited contributions from 'citizen scientists' in urban-

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based research in Australia, using experience from long-term studies we have been conducting on two large, charismatic species: the black swan (*Cygnus atratus*), and the eastern grey kangaroo (*Macropus giganteus*). Our goal in these studies is to collect long-term demographic data, particularly on movements and survival of individuals. Regular monitoring of individuals is essential for this purpose, but our study populations are large and mobile. Public contributions of sightings can potentially improve the frequency with which individuals are sighted, and thus improve the quantity and quality of our demographic data.

Drawing on a large sample of public reports, we evaluate how public information may change both public perceptions and reporting, and the potential for human populations to become a valuable source of information for research programs on urban wildlife. We are particularly interested in how two significant differences between our studies and Lowe's might make reconsideration of such questions worthwhile. First, the animals in our studies wear conspicuous identification marks, which are highly visible to the public. This presumably increases the chance that they will be noticed (and hopefully reported). Second, in the twenty years since Lowe's study, there have been remarkable advances in information technology. As a consequence, it is both easier for us to reach large segments of the public with information that might increase awareness and engagement (e.g. through the internet), and less onerous for them to contribute (e.g. via email, rather than dispatch by mail).

Research context

Black swans at Albert Park Lake

Our research over the last 10 years has focussed on the mating system and breeding ecology of the black swan (Kraaijeveld and Mulder 2002; Carew *et al*. 2003; Kraaijeveld *et al*. 2004*a*, 2004*b*; Guay and Mulder 2009). Since January 2006, this work has been conducted at Albert Park Lake, Victoria (37°50′S, 144°58′E), a 45-ha artificial body of water situated close to the central business district of Melbourne, which is home to a population of around 200 swans.

Studies of migratory waterfowl in the USA and Europe have long employed numbered neck collars for individual identification (e.g. Aldrich and Steenis 1955; Ballou and Martin 1964; Samuel *et al*. 1990; Alisauskas *et al*. 2006). After considering a variety of marking options, and confirming that these collars had no detrimental effects on the welfare of swans in our population (Guay and Mulder 2009), we adopted this method on a broad scale. Since November 2007, we have fitted all swans captured at Albert Park Lake ($n = 213$) with custom-designed (Spinner Plastics, Springfield, IL) lightweight rigid plastic collars (Guay and Mulder 2009). Each collar is engraved with a unique alphanumeric code consisting of one letter followed by two numbers (e.g. G95) repeated around the collar so that it can be read from most viewing angles (Fig. 1). To increase the information content of the collars and introduce some redundancy, we fitted females with white collars engraved with black lettering, and males with black collars with white lettering (the sexes have identical plumage and differ only slightly in size, and are thus difficult to sex in the field). Every collar had a unique number and therefore there was no overlap between the sexes in alphanumeric codes.

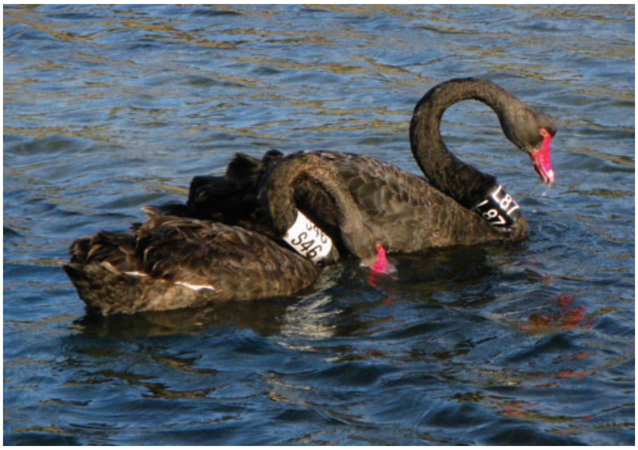

Fig. 1. Marked black swans (*Cygnus atratus*) at Albert Park, showing a male wearing a black collar with white lettering (right) and a female with white collar and black lettering (left). (Photograph: John Eichner.)

Eastern grey kangaroos at Anglesea

Our research on eastern grey kangaroos over the last 10 years has concentrated on foraging ecology and population management (Ramp and Coulson 2002; Maguire *et al*. 2006; Coulson *et al*. 2008; Davis *et al*. 2008; Garnick *et al*. 2010), with particular interest in overabundant populations (Coulson 2006). In November 2007, we began a project on urban kangaroos in the town of Anglesea, Victoria (38°25′S, 144°12′E), ~100 km south-west of Melbourne. The population of more than 300 kangaroos is centred on the Anglesea Golf Club (Inwood *et al*. 2008).

We have captured 162 kangaroos (120 female, 42 male) to date, most on the golf course and seven at a nearby school camp. We marked each individual with a unique combination of two or three coloured ear-tags (Allflex Australia, Brisbane) to which we affixed matching coloured reflective tape (3M Australia, Sydney) for identification at night. We also fitted all adult kangaroos with flexible collars made of UV-stable vinyl material (Innova International, Melbourne), cut into strips 8 cm wide, doubled over and held together with a PVC glue. To fit the collar, we overlapped the ends, punched four holes into them and fastened them with ratchet rivets (ITW Fastex General Products, Melbourne). We have used this marking system in our earlier studies of kangaroos (Poiani *et al*. 2002; Coulson *et al*. 2003), the collar alerting us to a marked kangaroo and the ear-tags coding its identity. To encode more information, we used white collars for all males, and three different colours (green, orange and yellow) for females corresponding to their capture location. Importantly for this project, we also gave each individual a unique three or four-letter name (e.g. 'Sav' and 'Kiwi') and, wrote the name two or three times around the collar with a black Allflex tag pen (Fig. 2).

Citizen sightings and reporting of tagged individuals

Both study sites are in urban areas with high levels of foot and vehicular traffic, giving significant exposure to the animals under study. Albert Park Lake is an important focus for community activities, recreation and major corporate events such as the Australian Grand Prix, and receives an estimated five million visitors per year. As one of the most visible elements of the lake fauna, collared swans attract considerable public attention. Anglesea is a popular holiday destination, located on the Surf Coast, and experiences a dramatic influx of visitors during the summer. It is also a popular tourist destination, marking the beginning of the iconic Great Ocean Road. Many tourists stop at the golf course specifically to view kangaroos, which are habituated and approachable.

We anticipated that the sight of tagged wildlife could cause emotional reactions among members of the public (Aldrich and Steenis 1955), so at both locations we embarked on extensive information campaigns about the tagging programs, both before and during their implementation. At Albert Park, signs were posted around the lake providing answers to frequently asked questions, and the research program and its focus were described in articles in local newspapers. The research team was often approached by members of the public in the field, and this provided another opportunity for the dissemination of information in person, or through the distribution of information leaflets. At Anglesea, we embarked on a similarly intensive awareness program. Our activities were centred around Kangaroo Awareness Week, held in August each year and aimed primarily at Anglesea residents. During the week, we gave talks to all year levels at the local primary school and to a range of community groups, and we spoke about the program at other meetings during the year. The program was also covered by a National Geographic documentary, *Kangaroo Kaos* (2009), local television and newspapers. To encourage reports of marked kangaroos around the town, we put up posters in shop windows and community noticeboards, and distributed contact cards to local organisations and interested individuals.

We primarily hoped to gain information from public reports on whether particular individuals were alive or dead at the time of reporting, and whether they had moved away from the location at which they had previously been sighted. In requesting reports, we explained the goals of the study and asked reporters to include at a minimum the following information: species, collar identity, collar colour, date of the sighting, location of the sighting, and whether the animal was alive or dead. We provided email addresses and telephone numbers to enable reporters to contact us by their preferred means. Although we typically obtained contact details from people who reported (which enabled us to follow-up on errors or request additional information), we did not request personal information.

Fig. 2. Marked male eastern grey kangaroo (*Macropus giganteus*) at Anglesea Golf Club, showing a white collar with black lettering and combination of coloured, reflective ear-tags. (Photograph: Graeme Coulson.)

Citizen reporting statistics

An astonishingly large proportion of people apparently either do not notice that the animals are tagged, are sufficiently unconcerned not to report a sighting, or perhaps lack information on where to make a report or lodge a complaint. It is difficult to estimate this proportion, but we generally receive fewer than twenty public reports of any nature from Albert Park in any year, which represents a minute fraction (<0.00001%) of the estimated number of annual visitors to the park. Visitor numbers to the golf course are not recorded, but we suspect that the reporting rate is similarly low in Anglesea.

Details of all public reports received for the two projects are summarised in Table 1. Between November 2007 and November 2009, we received a total of 1071 sighting reports of swans, or an average of 1.5 sightings per day. These sightings were contributed by 81 individuals, with a significant skew: the leader of one

Table 1. Characteristics of public reports of collared black swans and eastern grey kangaroos from Albert Park Lake and Anglesea, respectively

Study site	Black swans Albert Park Lake	Eastern grey kangaroos Anglesea
Collared individuals (*n*)	252	162
Females (%)	46	74
Males (%)	54	26
Total sightings	1071	90
Females (%)	49	40
Males (%)	51	60
Status		
Alive	1065	52
Dead	6	29
Injured	2	3
Collar only recovered	1	3
Near miss/collision	2	3
Local sightings[A] (%)	<2	13
Individuals sighted (%)	54	25
Sightings per individual	7.2	2.3
Sightings per day	1.5	0.1
Reporting errors (%)		
Erroneous	<5	5
Incomplete	<5	<5
People reporting (*n*)	81	50
Fraction same day/event (%)	<1	14
Reporting method (%)		
Email/letter	99	68
Telephone	1	14
Incident reports	0	5
In person	0	13

[A]Reports of collared individuals from within the perimeter of the study site itself.

dedicated group of individuals contributed 499 observations (47% of all sightings). Reports of kangaroos were fewer (90) but relatively more people (50) contributed. Contributors were primarily members of the public, but also staff of local agencies familiar with our research (e.g. Parks Victoria, Surf Coast Shire, Victoria Police). Almost all swan reports were made by email or letter, while a third of kangaroo reports came by telephone, personal contact or incident reports submitted to the wildlife agency, the Department of Sustainability and Environment.

Many reports were unsolicited, and in both studies the initial motivation for reporting was typically concern from members of the public about the neck collars. This concern often resulted from a lack of information. For example, many people in the swan study thought that the collar was refuse or debris that had become attached to the animal, rather than being an identification tool in scientific study; a surprising number of people reported a bird with 'a coke can stuck around its neck'. Another common source of concern in both studies was that the collars appeared tight, an impression caused by tufts of dense plumage or pelage that projected above and below the collars.

In both studies, public sightings included a substantial proportion of all collared individuals (swans: 54% of 252; kangaroos: 25% of 162; Table 1). Numerous individuals were reported more than once; in the swan study, the mean number of reports per resighted individual was 7.2 and the highest number of reports for a single individual was 48, while in the kangaroo study there were an average of 2.3 reports per individual, and the highest number of reports of a single individual was 14. Duplicate reports (i.e. those involving a sighting of the same individual at the same location on the same day) were extremely rare for swans, whereas they were relatively common for kangaroos. For instance, 14% of all 90 kangaroo reports involved multiple reports relating to deaths ($n = 4$ kangaroos; range 2–5 reports per individual).

In general, resighting reports from members of the public were quite accurate. Less than 5% of the 1071 total records provided did not match existing birds. However, in over half of these cases, the error involved a mistaken understanding of the alphanumeric system (e.g. '667' for 'G67') and was therefore easily rectified. Similarly, the low error rate for kangaroos (5%) resulted from mis-reading names, such as 'Gus' instead of the actual 'Guy'. However, as we discuss below, these estimates are conservative, since some errors (those that are erroneous but match an existing identity) are undetectable.

There were dramatic differences between the two studies in the spatial distribution of sightings, the proportions of each sex, and the nature of the report. Almost all of the swan reports came from outside the study site, from locations as far away as Ballarat (110 km) and Shepparton (178 km). By contrast, all kangaroos were resighted within 5 km of their point of capture. Male and female swans were equally represented among sightings, reflecting the proportions that were collared; similar numbers of collared males and female kangaroos were also reported, but almost three times as many female kangaroos were collared as males, suggesting a reporting bias towards male kangaroos ($\chi^2 = 4.3$, $P = 0.038$). Finally, the overwhelming majority (99%) of reports of swans were of birds that were alive, whereas a third (32%) of kangaroo records were reports of a dead animal.

Discussion

Public reports of sightings of collared animals were of considerable scientific value to our respective research programs, contributing over 1000 records in the swan study, and almost 100 records in the kangaroo study, and representing 25–50% of all collared individuals. One of the most striking differences between the two studies was that swan reports generally involved living birds in unusual places, whereas a substantial portion of kangaroo sightings were of deaths close to the study site. For the swan study, the network from which reports emanated covered a spatial scale (the state of Victoria) that far exceeded that which we could have explored with our modest resources. Thus, we obtained records of long-distance movements by individuals that we certainly would not otherwise have obtained.

In both studies, reports of animals both alive and dead enabled us to improve the quantity and quality of our demographic data, because we were able to detect and estimate the time of key events such as dispersal or mortality with greater accuracy, at a fraction of the cost that might have been involved if we had used more expensive technology such as VHF or satellite transmitters. The data also allowed us to interpret some causes of mortality, many (e.g. reports of near-misses or collisions with vehicles) resulting from the juxtaposition of human and animal populations in the urban ecosystem.

Over a comparable time period, we received an order of magnitude more public sightings for black swans than for eastern grey kangaroos. Numerous factors could plausibly have contributed to this difference. For instance, there were roughly twice as many collared swans as collared kangaroos, and the birds traversed a much larger range (and were thus exposed to a much larger pool of potential observers). The likelihood of sighting was almost certainly influenced by bird-watching being a much more common urban pastime than mammal-watching, and bird-watchers are often equipped with binoculars (which aid in reading of collars from a distance). Finally, a substantial fraction of the human population of Anglesea consists of seasonal tourists, who would have been less aware of the study or of what reporting channels were available to them, since most of our communication was directed at the permanent residents of the town.

It can be difficult to estimate the accuracy of citizen science data, since erroneous sightings can sometimes match genuine existing combinations by chance (Weiss *et al*. 1991). For instance, on the same day in August 2008, swan L02 was sighted both at Albert Park Lake by one of us (PJG), and reported from Edithvale Wetlands (25 km SE of Albert Park) by a member of the public. While it is conceivable that the bird could have been at both locations on the same day, the public sighting was probably incorrect, as an individual with a very similar collar (L03) had been seen at Edithvale repeatedly over the previous weeks. Mistakes are also evident when the report concerns collars of individuals either known to have died, or to have lost their collars (e.g. Craven 1979; Weiss *et al*. 1991; Madsen *et al*. 2002), and it has been estimated that such errors may represent up to 3% of all sightings (Weiss *et al*. 1991). We conducted an experiment on the swan population in which we asked an undergraduate class of 60 students to conduct a census of collared individuals. An alarming 25% of records did not match existing ones (and therefore must have been erroneous; R. A. Mulder, unpubl. data). However, we found that for public reports, the general level of accuracy was reassuringly higher (swans: >95%, kangaroos, >90%), probably because most reports involve encounters with animals at very close quarters, whereas the undergraduates attempted to identify birds from distances at which most casual observers would not even have noticed the birds were collared. The redundancies we built into our marking schemes (collar colour, alphanumeric configuration and ear-tag combination) were helpful in estimating error rates. For instance, in the swan study we were able to easily resolve erroneous reports that resulted from: a mismatch between code and collar colour; confusing symbols; or characters being read from bottom to top, rather than from top to bottom as intended (e.g. '555' [S55], '687' [L89] and '09N' [N60]). In the kangaroo study, redundancy was achieved through a combination of coloured ear-tags and a name on the collar. Few people reported tag combinations that were useable, either overlooking the tags entirely or confusing left and right ears. However, the names were extremely effective. Some observers 'adopted' individual kangaroos and provided regular updates on their activities. Most mistakes in reading alphanumeric marks involve a single symbol change (Weiss *et al*. 1991), but these were easily detected in both studies. We followed recommendations (Sladen 1973; Pirkola and Kalinainen 1984) to avoid similar characters (e.g. K versus X, 8 versus B, 1 versus I), ambiguous names (e.g. 'Don' versus 'Ron') or strings that could be confused when read in the wrong direction (e.g. O81 versus I80).

There is no doubt that the conspicuous nature of the collars has contributed to a significantly improved reporting rate: we previously tagged several hundred birds with only numbered leg bands and received only a handful of reports. However, the initial motivation for most unsolicited reports was concern about the welfare of the animals. While members of the public are presumably quite comfortable with collars on household pets, the unfamiliar sight of collared wildlife clearly provokes a range of reactions. Responses of citizens to the collars and tags ranged from indifference to curiosity, distress, and anger. Although we anticipated emotional responses, we were unprepared for the vehemence of some people. Saying that we needed to 'process' a captured swan led to comparisons with Nazi concentration camps; naming a large male kangaroo 'Ugly' (Fig. 2), although meant in gentle irony, generated equally strong reactions. We have learned to be more careful in our choice of words and names.

Although we mounted intensive local information campaigns, for the swans it was impossible to anticipate all the locations where collared individuals might appear. We found that in most cases, concerns were alleviated once we had explained the goal of the study and clarified that the collars did not impact on the well being of the animals. One gratifying outcome of this investment in public information is that initially sceptical observers often subsequently become regular contributors of sightings in their local area. We observed a similar change in attitude among park rangers, golf club ground staff and welfare officers, who initially held reservations about the collars, but learned to appreciate their value.

The fact that most initial reports are motivated by concern about the welfare of the animals raises interesting questions about our investment in information campaigns about the research programs. In our experience, once reassured about welfare issues, most members of the public became accustomed to the markers and did not make further reports. Effective information dissemination about the research and its objectives may therefore have the paradoxical and unintended effect of reducing the frequency of unsolicited reports.

Clearly, any future approach must minimise public concern without discouraging regular and accurate reporting. One profitable strategy may be to enlist groups of nature enthusiasts. Researchers working on waterfowl often publish short articles in journals and newsletters of birdwatcher, bird bander or field naturalist groups to request data (Barry 1956; MacInnes 1961; Braithwaite 1966; Sladen 1972). For the swan project, we targeted members of Birds Australia and Bird Observation & Conservation Australia and published a short note in their newsletters informing members of our project and how to report their sightings (Mulder 2008; Wood 2009). The kangaroo project evolved from a community-based kangaroo management plan for Anglesea (Inwood *et al*. 2008). The plan advocated a process of people learning to live with kangaroos, and identified a strong desire among residents to learn more about kangaroos in their area, which led to the research we have been conducting. Management actions, including our research, are overseen by the Kangaroo Advisory Group, which has representatives of government agencies, private industry and local conservation groups.

We believe that the substantially higher rates of reporting we obtained in this study compared with Lowe's two decades ago have resulted primarily from the conspicuous nature of the collars our animals wear. However, we suspect that technological advances have also played a part in facilitating the reporting of sighting. While most of the information about our research was disseminated via print media and television, almost all of the reports for swans, and most of the reports for kangaroos, were received via email. Email permitted us to send rapid feedback to reporters, which in many cases encouraged them to send subsequent reports.

In North America, websites provide another convenient portal for submission of data (Canadian Wildlife Service 2008). However, these websites are limited in that they typically involve only one-way transfer of information (from reporter to database). We believe that there is great potential for a much more satisfying, interactive model. Under this model, a website could offer not only the opportunity to submit data electronically, but to also provide instant, automated feedback, including information about the history of the marked animal for which data were submitted. Such a site could provide not only static answers to frequently-asked questions about the collars and the project, but also a moderated discussion forum and the opportunities to interact with like-minded individuals to share information and experiences, forming clusters of contributors. A website could also help direct observers to areas with low reporting rates, and reiterate instructions to reduce the rate of incorrect or incomplete reports. The proliferation of mobile devices make it possible to develop applications for 'smart phones' that would allow citizen scientists to submit reports to the website in real time, automatically reporting location and time, as well as checking for errors.

Conclusions

Our analyses of citizen science data that contributed to our two studies suggest that these reports can be voluminous, are often unique and are generally reliable. Thus, such reports can supplement scientific research in important ways. Advances in information technology will play a key role in improving our ability to raise public awareness about the research programs and allowing people to submit reports more conveniently.

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