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Novel tracking and reporting methods for studying large birds in urban landscapes

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Monitoring individually marked birds' movements over the long term with the aid of third-party observers can be challenging for reasons including poor tag visibility, observer error and tag failure or removal. This study tested the efficacy of the little used method of tagging birds with livestock ear-tags; fitted to the patagia of 100 sulphur-crested cockatoos occupying an urbanised landscape. The wing-tags were easily applied, persisted over four years, and were highly visible. Urban residents were encouraged to report sightings of tagged birds, and there was a strong public response, with a total of 14 705 valid records over the first four years. Wing-tagged birds were predominantly reported through a customised smartphone application (n = 10 146 records), e-mail (n = 3243), Facebook (n = 415), and other formats (n = 901) by a large number of people (n = 1252) across all formats. All 100 tagged birds were reported by third-party observers at least once and 68% of birds were reported more than 100 times. Because large birds tend to dominate urban bird communities, this research methodology should be effective for many other urban ecology projects.

Many fundamental questions in animal ecology require the estimation of population size, assessment of movement, measurement of habitat preference, and interpretation of group and individual behaviours (McDonnell and Pickett 1990, Dingle 1996, Savard et al. 2000, Marzluff 2001, McKinney 2002, Kark et al. 2006, Grim et al. 2008, Sol et al. 2013). Uniquely marking a subset of individuals in a population is an important research method used to answer a range of questions, and marking technologies have advanced considerably over the past century, from leg banding birds to satellite tracking of sharks (Calvo and Furness 1992, Horback et al. 2012, Jorgensen et al. 2010, Martin and Major 2010, Recio et al. 2011, Votier et al. 2011). All marking methods involve costs, both in terms of animal welfare or fitness (Sikes and Gannon 2011), and financially, with some marking methods costing several thousands of dollars per animal. Projects are commonly designed to accommodate these costs by using either a large sample of animals marked using a method that is minimally invasive and inexpensive (e.g. bird banding or fish tagging) (Marion and Shamis 1977), or a small sample temporarily fitted with a more invasive and expensive technology (e.g. GPS transmitters) that produce much larger individual datasets (Jorgensen et al. 2010). Low-technology projects often require the assistance of third-party observers to collect sufficient data. The integration of mobile technology and citizen science has the capability to increase data capture associated with 'inexpensive' methods such as bird marking. This is likely to be most successful in urban areas, where there is more reliable mobile coverage and a larger pool of public participants.

A fundamental theme of research directed towards the conservation of wildlife populations in urban areas is the development of an understanding of urban resource availability, particularly food and shelter (Shochat 2004, Chace and Walsh 2006, Shochat et al. 2006). Tree hollows can be a key limiting resource in human-modified landscapes, and competition for nesting cavities can impact on population abundance and species diversity at a local and regional scale (Humphrey 1975, Soderquist and Mac Nally 2000, Harper et al. 2005, Davis et al. 2013). In several Australian cities, the native, hollow-nesting, sulphur-crested cockatoo *Cacatua galerita* has modified its behaviour to exploit urban environments and now dominates use of large urban tree hollows (Davis et al. 2013). The expansion in the range of this species and its associated increase in abundance in urban coastal areas over the past 45 years (Gibson 1977, Morris 1986, Higgins 1999) is paradoxical, given the scarcity of tree hollows in this environment (Davis et al. 2013, 2014). To understand this paradox it is necessary to determine the scale over which urban cockatoos nest and forage.

Marking birds to research migration, survival and other aspects of ecology is an established research technique (Calvo and Furness1992). Parrots, however, have received less attention, compared to other bird orders, partly due to difficulties inherent in catching, attaching monitoring equipment and tracking (Rowley and Saunders 1980, Lindsey et al. 1991, Salinas-Melgoza and Renton 2005). Nonetheless, a number of studies have used patagial tagging techniques to collect information on the breeding, dispersal and population size of parrot species (Rowley and Saunders 1980, Saunders 1988, Smith 1991). These studies have had mixed success, with one study finding higher mortality rates in birds fitted with metal tags compared with birds fitted with leg bands (Rowley 1983). More broadly, concerns exist regarding the method of patagial tagging and the risk of physical injury, social rejection, breeding failure and predation (Lank 1979, Saunders 1988, Kindkel 1989, Bustnes and Erikstad 1990). Studies have, however, successfully used plastic live-stock ear tags attached to the patagium of other species, including vultures (Family Accipitridae) (Wallace et al. 1980, Anderson and Anderson 2005, Kendall and Virani 2012, Reading et al. 2015), Australian white ibis *Threskiornis molucca* (Martin and Major 2010) and Australian pelican *Pelecanus conspicillatus* (Waterman et al. 2014) with no detrimental effects reported.

The placement of highly visible and easily identifiable patagial tags on a bird, coupled with new technologies which have broad scale community access and functionality, provide ideal conditions to recruit citizen scientists for data collection (Irwin 1995). Engagement of the public to collect scientific data is becoming increasingly common; people are enlisted to report sightings of wildlife, or other natural phenomena (Savan et al. 2003, Whitelaw et al. 2003, Toms and Newson 2006, Szabo et al. 2010, Hobbs and White 2012). Also increasingly common is the use of social media networks to engage the community and promote projects (Barve 2014, Graham et al. 2014, Starbird et al. 2015), as well as smartphone technology to collect data (Burr et al. 2014); both social media networks and smartphone technology have been shown to be successful in citizen scientist projects. In this study we evaluate patagial wing-tag retention by sulphur-crested cockatoos and community use of technology to report sightings in a research project known as 'Cockatoo Wingtag'.

Methods

Study site

The study was undertaken in Sydney, New South Wales, Australia, and birds were captured in the Royal Botanic Garden, a predominantly open space of 64 ha bordering Sydney Harbour and located within the central business district. The Royal Botanic Garden supports several large hollow-bearing *Eucalyptus* trees, which provide nesting habitat for hollow-dependent fauna, as well as extensive lawns and plantings of a mix of native and exotic species. Wing-tagged birds (Fig. 1) were resighted in urban areas of Sydney, mostly within a 20 km radius of the Royal Botanic Garden, in habitats ranging from the balconies of high-rise inner-city units to suburban parkland.

Figure 1. Wing-tagged sulphur-crested cockatoo at (a) inner city office building, and (b) a tree hollow.

Capture and tagging

The Royal Botanic Garden is home to a seasonally variable population of sulphur-crested cockatoos with up to 150 individuals present at any one time (Martin unpubl.). Between September 2011 and January 2014, 100 individuals were captured and tagged. The Royal Botanic Garden has a high level of both local and tourist traffic, many of whom interact with and/or feed the sulphur-crested cockatoos. As such the birds have habituated to human contact and we were able to lure them to the ground with seed, and each bird was captured by hand, with the catcher wearing protective wildlife handling gloves. Once caught, the bird was placed into a pillowslip to minimise distress and was then taken out of public viewing for processing. Birds were weighed and then banded with a numbered Australian Bird and Bat Banding Scheme leg band. A size-2 yellow plastic livestock ear-tag (<www.leaderproducts.com.au>), with overall dimensions of 54×48 mm and displaying three foil stamped black digits, was then attached to each wing, using a livestock ear tag applicator (Martin and Major 2010). Small studs (16 mm rather than 25 mm base width, <www.nationalband.com>) were used in order to reduce the chance of rubbing against the flight muscles (Fig. 2). The point of insertion was selected so that the tag was prominent on the folded wing (Fig. 2), and was also well away from the flight muscles and any major blood vessels (alcohol gel was used to smooth feathers, allowing clear visual assessment of the patagium). No feathers were removed. Tags bearing the same number were applied to each wing and positioned approximately 7 cm proximal to the ulna-metacarpal joint.

Reporting of sightings

Initially, information about the project and how to report sightings of tagged cockatoos was included on the Royal Botanic Garden website (<www.rbgsyd.nsw.gov.au>), and a dedicated e-mail address was promoted through partner institutions and relevant wildlife and environmental agencies. Reporting via e-mail or phone allowed the core data

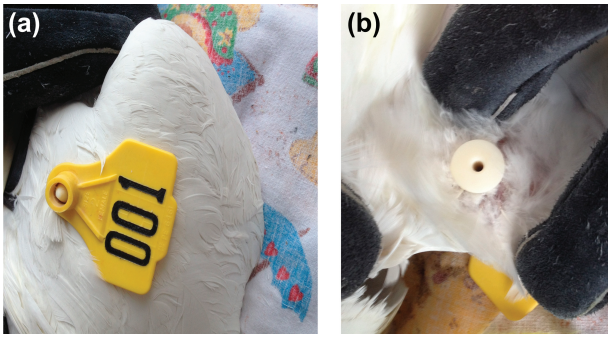

Figure 2. Patagial tag (a) on dorsal side of wing, and (b) showing the stud base of a wing-tag on a bird recaptured 24 months after tagging, showing the ventral patagium and undamaged feathers.

of tag number, location, date and time of the sighting, as well as any other ancillary information (e.g. tag loss) to be recorded. Any omitted information could usually be obtained by direct follow-up contact with the reporter. A Facebook page (<www.facebook.com/cockatoowingtags>) was established in March 2012 with the purpose of promoting the project and creating a space for sharing information. This provided an additional method for the submission of reports by the public, but captured less rigorous data because details such as time, date, location or tag number would occasionally be omitted and direct follow-up contact was not always possible. An iPhone application (app, hereafter) was developed and released in April 2012, which mirrored the data collected through e-mail and phone reports and also provided the capacity for the submission of automatically geolocated reports, including a photo (iOS Appstore: Wingtags). Importantly, the app provided a feedback mechanism ('Cockystream') by which participants could view the 50 most recent sightings of birds, including the date, location and photograph (if submitted). The submission of photographs with each report provided an opportunity for verification of the accuracy of the report, however photo submission was not mandatory and so this process could not be implemented for all reports.

Data analysis

Data were checked to eliminate reports that lacked sufficient information (e.g. missing location, date) or were outside of Australia (e.g. reports from Europe) The remaining data, from 11 September 2011 to 31 August 2015 were included in the analyses.

To determine the rate of wing-tag retention, we evaluated anecdotal reports of tag loss. After a reporter had indicated that only one tag was present on a bird, we asked them to confirm with a photograph showing the remaining tag or a distinguishable leg band. If this was not possible, we used a second independent confirmation. A tag was deemed to have been lost if there were at least two independent records stating that one tag was missing, and ideally a photo. Occasionally the loss of two tags was detected when an observer reported the numbered leg band. A Fisher's exact test was used to determine whether the confirmed loss of two tags occurred at the same incidence as predicted from the loss of a single tag.

The method by which participants reported observations (app, e-mail, Facebook) was compared, and differences in reporting rates between methods were assessed with linear mixed models (IBM SPSS ver. 19), measured by the number of reports per method per bird, with the number of days that each bird had been tagged as a covariate. Reports received via other formats prior to the app being operational were not included in the linear mixed model analysis or in the following calculations. Variation in reporting rates through time were analysed by comparing annual reporting rates, with years measured from the beginning of spring (1 September) through to the end of winter (31 August). The longevity of community participation from year 1 was determined by calculating the percentage of people who submitted a report in subsequent years. The same percentages were calculated for people that commenced reporting in year 2 and were still reporting in years 3 and 4.

Results

Tag retention and sightings

All 100 cockatoos were resighted, with 68 % of birds sighted over 100 times (Fig. 3). Twelve birds removed one tag (three birds removed the left tag and nine removed the right tag), and five birds removed both tags. Given that 17% of birds lost at least one tag, we would expect on average 2.89 birds ($0.17 \times 0.17 \times 100$) to lose two tags if losing each tag had the same independent probability. The observed two-tag loss frequency ($n = 5$) was not significantly different from the expected value ($p = 0.31$), suggesting that particular birds were not prone to tag removal. There was a 95% tag retention rate for at least one tag remaining on a bird over the four years ($n = 95$), and an 83% retention rate for both tags remaining on a bird over the same period ($n = 95$).

Five birds (5%) were reported (either by phone or e-mail from local wildlife agencies) to have died over the four years. Two birds died from car strike, two from Psittacine beak and Feather disease and one from an unknown cause. At least four tagged birds are known to have successfully fledged young and several tagged birds have been observed displaying courtship and bonding behaviour with untagged birds (determined by photos and accounts provided by members of the public, as well our direct observations). No adverse effects, such as shunning from the flock, increased predation or damage to the wing have been observed.

Reporting outcomes – no. of reports

A total of 15 282 sightings of tagged birds were reported from all reporting formats, of which 577 (3.8%) were considered erroneous, resulting in 14 705 valid reports. Of the valid reports, the app received 10 146 (69%) reports, e-mail 3 243 (22%) and Facebook 415 (4%). Reports were also received through 'other formats', including the Australian Bird and Bat Banding Scheme, Twitter, phone, and mail, totalling 901 (6%). There were 53 (0.3%) erroneous reports received via non-app formats, which lacked sufficient information (e.g. location) or reported a tag number that was known to be incorrect.

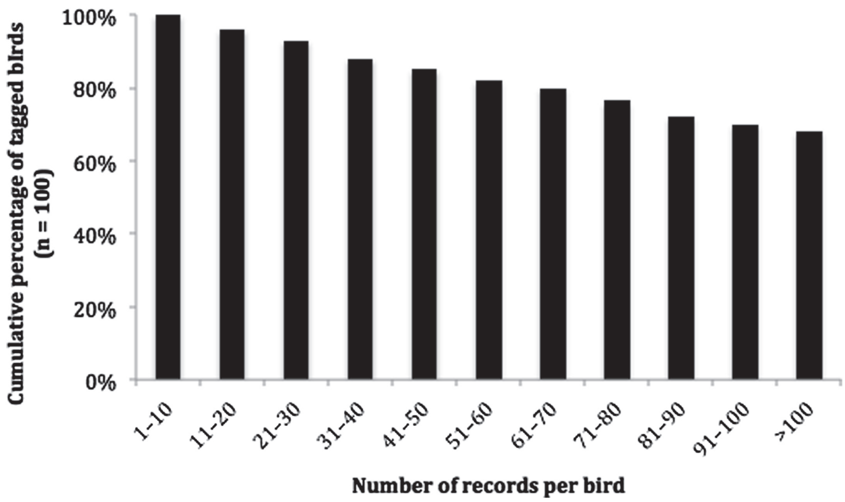

Figure 3. Resighting frequency of 100 tagged sulphur-crested cockatoos over a four-year period.

The major source of erroneous data was the absence of positional information. A total of 10 670 reports were received via the app, but of these 382 (4%) failed to geolocate yet contained a note (written entry) of the location, while 524 (5%) were considered erroneous as the app failed to geolocate and no interpretable note was included.

On average 30 (SE ± 3.0) reports were received per bird (n = 100) during the first six months post tagging. The number of reports received per bird ranged between one and 85, with the majority of reports submitted via the app.

Comparison of reporting formats

A total of 1252 unique people contributed reports over the four years. The largest number of unique contributors (n = 709) reported sightings via e-mail. This was followed by the app (n = 328) and Facebook (n = 185), with the remainder contributing via other methods. On average people using e-mail reported 1.9 (SE ± 0.09) individual birds and made 4.2 (SE ± 0.55) reports. People using the app reported 6.6 (SE ± 0.60) individual birds and made 23.6 (SE ± 0.25) reports on average. People using Facebook reported 1.8 (SE ± 0.17) individual birds and made 2.2 (SE ± 0.25) reports on average.

Frequency of reporting

The highest number of reports per week was received via the app, with 58 (76%), followed by e-mail (16; 21%) and Facebook (2; 0.3%). The difference in reporting rates between formats was significant ($F_{(2,297)} = 243.00$, $p < 0.001$) with the app receiving the highest number of reports per bird, compared with e-mail and Facebook. The number of reports via the app increased from 1 625 in the first year (n = 44 birds tagged) to 3284 reports in the second year (n = 74) and 3964 reports in the third year (n = 91). However, the reports decreased to 1905 in the fourth year (n = 90). After the first year, there was minimal variation over the subsequent three years in the number of reports received via e-mail and Facebook (Fig. 4).

Community participant rates

Rates of participant attrition were lowest for the app, compared with e-mail and Facebook, with a higher percentage of people from the first year of the project submitting reports by the end of year four (Fig. 5). Less than 5% of people who submitted reports via e-mail and Facebook in year one were submitting reports in year four (Fig. 5).

Discussion

The use of plastic live-stock ear tags as patagial markers on sulphur-crested cockatoos resulted in a 100% resighting rate and 14 705 valid resightings over four years. The resighting rate was higher than that reported for livestock ear tags in the Australian white ibis (Martin and Major 2010) and for vultures (Family Accipitridae) (Anderson and Anderson 2005, Kendall and Virani 2012), though it is important to note that the latter two studies were undertaken in less human-populated regions.

There was a high rate of tag retention (95%), as has been observed in previous studies using patagial tags (Wallace et al. 1980, Martin and Major 2010). No fading of tags was observed, but at least two cockatoos partially chewed one

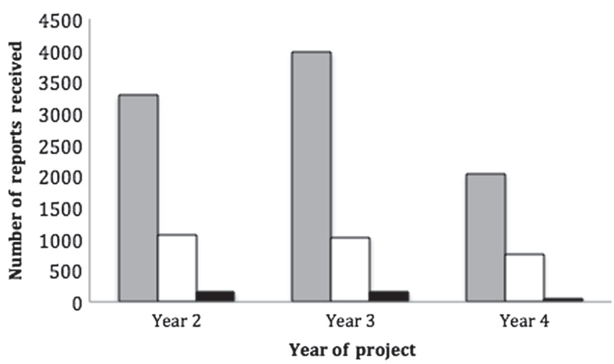

Figure 4. The number of reported sightings received via the iPhone app (grey bar), e-mail (open bar) and Facebook (black bar).

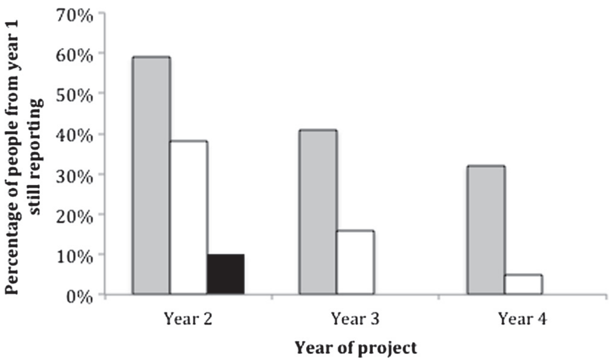

Figure 5. Proportion of people who reported wing-tagged cockatoo sightings in year one who continued to report in subsequent years; app (grey bar), e-mail (open bar) and Facebook (black bar).

of their tags, enough to obscure the identification number on either the left or the right side. Birds that removed their tags appeared to have done so by biting through the plastic stud that attaches the tag to the wing, with the tag then falling off. Removal of tags appeared to be random in the sense that birds that had removed one tag were no more likely to remove their second tag than predicted by the single-tag removal rate. However, given the difficulty of identifying birds that had removed both tags, and the relatively small sample size for tag removal, this conclusion must be considered preliminary. Of the 24 birds that were unaccounted for at the end of the four-year period, five were known to have lost both tags and five were known to have died, the remaining 14 birds may have lost both tags, rather than being dead or not being reported. Whilst it is possible that members of the public removed tags, we believe that tag removal was most likely due to the bird itself. A small number of recovered tags showed evidence of chew marks and sightings and photos of the birds showed chew marks on the tags in situ before they were removed.

Plastic livestock ear tags appear to be superior to metal patagial tags previously used on *Cacatuidae* sp. (Rowley and Saunders 1980, Saunders 1988), with this study recording no tag related injuries, deaths or adverse effects amongst any of the 14 705 reports submitted by 1252 people. Increased predation of *Cacatuidae* sp. by raptors as a result of metal-disk patagial tags has previously been reported (Rowley and Saunders 1980, Saunders 1982, Rowley 1983), however we saw no evidence of this for the sulphur-crested cockatoos. Nonetheless, it is important to note that there are likely to be fewer raptors in urban Sydney, compared to the agricultural and woodland locations of the previous studies. Upon re-examination of the patagia of recaptured cockatoos (n = 8) between 12 and 36 months after tagging, all were healthy with no signs of abrasion or wear, consistent with studies on other species (Wallace et al. 1980, Martin and Major 2010). We observed no negative impact in regards to social behaviour, with allopreening behaviour observed between tagged and untagged birds, and successful breeding behaviour. There is a lack of information regarding the breeding biology of wild sulphur-crested cockatoos (and other Cacatuidae sp.), and studying birds individually marked with plastic livestock ear tags is a cheap and effective alternative to telemetry that may assist future researchers to investigate the age of initial breeding, pairing, breeding longevity and frequency of breeding in wild populations. Our study has demonstrated that plastic livestock ear tags can be successfully used on a large bodied parrot, which has implications for researchers of other parrot populations throughout the southern hemisphere, with identification of individuals within the population easily achievable. Additionally, the success of the community engagement with, and reporting of, the plastic livestock ear tag means that populations of other abundant large birds throughout cities in both the northern and southern hemisphere (Tortosa et al. 2002, Vuorisalo et al. 2003, Martin et al. 2010, Bachir et al. 2012, Minor et al. 2012) can be individually monitored by researchers and the community using this method.

The highest number of wing-tag sightings was submitted through the smartphone app. E-mail, whilst being the format that received the highest number of unique contributors and the second highest number of reports, received only a third of the number of reports compared with the app. The large volume of reports received via the app is consistent with the success of smartphone technology in other environmental community citizen science projects (Burr et al. 2014, Pennington et al. 2015). The widespread use of 'smart' devices, combined with their capacity to install apps and take and upload geolocated photos makes them both a rapid and a rich source for data reporting (Pennington et al. 2015) that is spatially and temporally accurate. However, a major limitation of our study was that the app we used was only available on iOS, and was not available for use on Android phones. (Many Android users contacted us directly asking for an app they could use.) Preference for the app over e-mail and/or Facebook may be due to the ease at which a report can be submitted at the moment of the sighting. An additional benefit of the app was that it provided instant feedback at the time an observer was watching the bird. We assigned a name to each bird (e.g. 001 = Columbus), and upon uploading the wing-tag number, the app-user was informed of the corresponding name of the bird they reported. (Anecdotal feedback indicates that this naming feature was extremely popular, and later in the project, participants volunteered financial support for the project in return for naming newly-tagged birds.) In addition, the resighting appeared in the apps viewable 'Cockystream'. Feedback to participants is an important component of citizen science projects (Bonney et al. 2009), and the 'Cockatoo Wingtag' app not only provided instant feedback by supplying the name of the bird, but also provided a motivation to view the 'Cockystream' section of the app independently of reporting a sighting to see where else a particular bird may have been sighted (and to view a picture, if submitted).

Facebook received both the fewest reporting submissions, compared to e-mail and the app, as well as the lowest number of unique users who submitted reports. It is important to note that Facebook was originally established as an engagement tool, rather than a primary reporting channel, but it was co-opted as an additional reporting method by users. Even though collecting reports was not its purpose, Facebook still received a higher number of reports than the official reporting option of the Australian Bird and Bat Banding Scheme (ABBBS). This is presumably due to the higher level of community awareness and promotion that can be achieved by social media, as well as engagement of different demographics and the ease of reporting being akin to messaging a friend.

Whilst social media networks have proven to be a successful tool for citizen science projects (Barve 2014, Pennington et al. 2015), their effectiveness often appears to lie more in passive data collection and promotion. The success of Facebook in the study of Barve (2014), was through promotion of the research project, and specifically the app that was used to report data. Facebook fulfilled a similar role in our study by promoting the project and engaging with the public. The Cockatoo Wingtag Facebook page had an audience of ~20 000 'likes', with individual posts often receiving upwards of 80 000 views from sharing. Through this communication channel we regularly disseminated feedback of the project's progress (e.g. longest distance travelled, new birds tagged), and we have the potential to reach a large audience. Facebook (and other social media networks) also has the capacity to allow people living outside the study area to indirectly engage with and learn from the project, potentially receiving similar benefits to people participating in the project, such as an increased awareness of environmental issues (Brossard et al. 2005, Devictor et al. 2010).

In conclusion, plastic live-stock ear tags have proven a successful patagial marking method for sulphur-crested cockatoos, with a high tag retention rate, high resighting rate and zero tag-related injuries or mortalities. This marking and reporting method was very successful due to the high human population density in the study area and the iconic status of the study species. Whilst the app received the highest number of reports, the largest proportion of reporters initially made contact via e-mail, and subsequently found out about the app. E-mail also provides an alternative reporting option for people who may not have a smartphone, but the downside is that a large volume of e-mails can become difficult to process, as opposed to the app which feeds directly into a database. We found social media to be a valuable adjunct to volunteer reporting, not so much as a reporting tool in itself, but as a means of recruiting volunteers and for providing feedback to enhance community engagement.

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Permits – Birds were banded under an Australian Bird and Bat Banding Scheme licence (267901). Approval to catch and tag birds was granted under New South Wales Scientific License (100107). The Office of Environment and Heritage animal ethics committee granted approval for this research (151020-01). There is no conflict of interest to declare for any of the authors.

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