Transactions of the Royal Society of South Australia

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/trss20

Implementing a citizen science bird monitoring project in the Grampians/Gariwerd National Park, Victoria, Australia

Gregory D. Kerr & Hannah Auld

To cite this article: Gregory D. Kerr & Hannah Auld (12 Apr 2024): Implementing a citizen science bird monitoring project in the Grampians/Gariwerd National Park, Victoria, Australia, Transactions of the Royal Society of South Australia, DOI: 10.1080/03721426.2024.2341350

To link to this article: https://doi.org/10.1080/03721426.2024.2341350

Published online: 12 Apr 2024.

TRANSACTIONS OF THE ROYAL SOCIETY OF SOUTH AUSTRALIA
https://doi.org/10.1080/03721426.2024.2341350

Taylor & Francis
Taylor & Francis Group

Check for updates

Implementing a citizen science bird monitoring project in the Grampians/Gariwerd National Park, Victoria, Australia

Gregory D. Kerr[a] and Hannah Auld[b]

[a]Nature Glenelg Trust, Hamilton, Australia; [b]Parks Victoria, Halls Gap, Australia

ABSTRACT

Global bird populations are threatened by ongoing habitat loss and climate change. Inconsistent and short-term funding of faunal surveys in Australia makes population and distribution changes difficult to detect. To meet this challenge, alternative methods of supplementing regular surveys by professional ornithologists have been proffered, including surveys by trained citizen scientists. Here we outline the development, implementation and assessment of the Great Gariwerd Bird Survey (GGBS), a citizen science (CS) monitoring project designed to address long-term management questions in vulnerable Stringybark Heathy Woodland in Grampians/Gariwerd National Park. Forty volunteers that met appropriate criteria were selected and trained in practical 10-week/40-h courses. We assessed data from 288 2-ha/20-min surveys undertaken in autumn and spring 2021 at 36 sites, ran workshops to improve surveyor skills and data quality and assessed trainee experiences and program content through online anonymous surveys. Concurrent professional field ornithologist surveys enabled cross validation of CS surveys. Overlapping species accumulation curves for professional and citizen scientist surveys reflected very high correlations for site species diversity ($r = 0.836$) and abundances ($r = 0.768$). In autumn, the professional surveyor recorded significantly more species and birds than CS surveyors. Additional training in the identification of cryptic birds and challenging calls partially addressed the numerical differences in the following spring survey. This project demonstrates the potential for valuable long-term ecological data collection by well-trained citizen scientists with benefits to community environmental knowledge and participation despite some manageable obstacles. Participant surveys showed highly positive program perceptions, reflected by ongoing involvement in the GGBS.

ARTICLE HISTORY
Received 6 January 2024
Accepted 7 April 2024

KEYWORDS
Citizen science; training; bird survey; Grampians Gariwerd National Park; program design

Introduction

The use of volunteers or "citizen scientists" to gather data is a research technique that enlists the public in gathering scientific information or participating in scientific endeavours. Such programs are increasingly being funded for many aspects of environmental and conservation management by Australian governments (Conrad & Hilchey, 2011; Wolcott et al., 2008). Designing, implementing and maintaining an effective citizen science program requires a multi-faceted iterative approach to achieve participant engagement and

CONTACT Gregory D. Kerr greg.kerr@ngt.org.au Nature Glenelg Trust, 24 Clarke Street, Hamilton VIC 3300, Australia

retention, data quality assurance and bias correction, connections to community, environmental awareness and data sharing (Adler et al., 2020; Fraisl et al., 2022).

This project – The Great Gariwerd Bird Survey (GGBS) – was established in 2021 to foster a citizen science (CS) monitoring program to evaluate changes to the avian community in the vulnerable Heathy Woodlands (Parks Victoria, 2019) and inform management actions as part of an adaptive management cycle in the Grampians/ Gariwerd National Park (GGNP) in Victoria, Australia. The GGBS project is designed to detect patterns of species occurrence over a long period and a large area, and as such is especially well suited for a CS program (Adler et al., 2020; Bonney et al., 2009). Through tracking ecosystem parameters over time, CS can provide crucial baseline information on the effects of global change (Conrad & Hilchey, 2011) and identifying locations with good and poor environmental condition (Jarvis et al., 2015). Citizen Science data can map the spatial distribution of species (Horns et al., 2018) and changes in abundance and distribution (Abolafya et al., 2013; Neate-Clegg et al., 2018). By choosing a longitudinal approach with surveys based at a network of stratified sampling locations in which species occurrence and relative abundance are collected at regular times each year, this project aims to avoid known limitations to cross-sectional atlas-based CS projects (Tulloch et al., 2013).

Citizen science derived avian diversity and abundance data can provide similar information to professionally collected monitoring programs (Szabo et al., 2012). The current concept of CS, with its integration of explicit and tested protocols for collecting data, vetting of data by professional scientists, and inclusion of specific and measurable goals for the education of the citizen scientists, has evolved primarily over the past 20–30 years. Previously, most research projects relied on scientists to design, implement and carry out the monitoring; however, such projects are costly, generally short term and are restricted to relatively small areas (Lindenmayer et al., 2014a), with intermittent funding often resulting in a premature end to the project (Kerr & Gully, 2023). In contrast, CS projects can facilitate more extensive data collection that would not be possible if the scientist had to collect data on their own. Citizen science gives increased community awareness and appreciation of the process of scientific enquiry (Peter et al., 2019). It gives enhanced potential for the implementation of scientific findings as well as promoting and valuing local knowledge (Peter et al., 2019). Citizen science lends itself to facilitation of democratic participation in decisions made by society and rebuilding of social capital reducing costs. Importantly, it offers an increased ability to implement wide-scale and long-term monitoring projects (Adler et al., 2020; Fraisl et al., 2022; Greenwood, 2007; Lindenmayer et al., 2014a).

To address a shortage of skilled observers and reduce observer bias, a relatively comprehensive training program, tutored by experienced observers (Bibby et al., 2000; Hanowski & Niemi, 1995; Kepler & Scott, 1981), is required. In the western district of Victoria, membership of regional bird and natural history groups has been declining over decades, with many groups scaling down their work in environmental monitoring (GK *Pers. Obs.*). This parallels the decline in knowledge of natural history in developed economies in recent times (Tewksbury et al., 2014) with knowledge holders predominantly from an older demographic (Wolcott et al., 2008).

Development of effective bird identification and monitoring skills requires hundreds of hours of effort over many years to build and fine tune (Kelling et al., 2015). For most people, the process of learning bird species identification is *ad hoc* and opportunistic, involving many years of slow accumulation of knowledge with infrequent chance observation of many species. Consequently, skill levels in detecting and identifying species often vary markedly among surveyors (Kelling et al., 2015). Even where relatively "experienced" observers are involved, a rigorous observer training program reduces, but does not eliminate, variation in counts between observers (Kepler & Scott, 1981).

Identification and counting of all birds present in a 2-ha/20-min survey is technically demanding, particularly when diversity, abundance and bird activity levels are high and in dense habitat (Bibby et al., 2000). For birds that are seen, factors such as illumination, movement, foliage cover and distance to the bird, together with the effect of environmental variables such as wind strength and cloud cover mean that observation is often brief, partial and typically incomplete (Bibby et al., 2000). Consequently, to successfully undertake a bird survey requires a detailed topological knowledge of all species likely to be in a habitat, but importantly the ability to identify them independently of visual observation through binoculars. For many habitats, most species therein are identified by call, without visual confirmation. Nevertheless, accurate auditory identifications can be difficult (Bart, 1985; Farmer et al., 2012; Kepler & Scott, 1981). The problems of observer bias and error in acoustic bird surveys are well known (Bart, 1985; Farmer et al., 2012; Kepler & Scott, 1981). Even expert observers under-count, over-count and misidentify birds (Bart, 1985), and data collected by auditory surveys generally incorporate some observation error. However, McLaren and Cadman (1999) demonstrated that interested volunteers with low to moderate skill levels can be trained to identify and count a subset of forest birds, by song or call, well enough to provide credible data on those species, and volunteer surveys can be scientifically valuable if analysed appropriately (Farmer et al., 2012). Prior teaching in a classroom environment, a cooperative and learning centred environment and follow-up field trips to apply skills all add substantially to knowledge learnt (Kepler & Scott, 1981; Randler & Bogner, 2002).

For a CS project to be effective, it must address volunteer interests and needs. Communication with volunteers in terms of goal setting, supervision and feedback are important determining factors for volunteer involvement (Antos et al., 2006; Weston et al., 2003). Volunteers desire activities on highly threatened birds and prefer outdoor activities that are not costly to them. Wolcott et al. (2008) found that the bird monitoring program volunteers' key motivation was helping to conserve birds and habitat. Few volunteers are interested in contributing to administrative support, thus the need for paid staff to carry out administrative tasks in such programs (Weston et al., 2003; Wolcott et al., 2008). A review of long-term participants in volunteer bird monitoring projects found that nearly half sought pairing with an expert on field trips, and over 40% indicated workshops on species identification would be beneficial (Wolcott et al., 2008).

The GGBS project has the potential to provide a cost-effective monitoring program for Parks Victoria in GGNP, with similar information quality to professionally collected data (Szabo et al., 2012) that informs and involves the broader community. This provides important benefits to Parks Victoria and their management of biodiversity within the GGNP.

This paper details the development, implementation and assessment of the GGBS. Critical to effective project implementation was the training and support of a new cohort of bird survey volunteers. Reporting rates from concurrent surveys collected on seasonal bird diversity and abundance by both 40 citizen scientists and a professional field ornithologist are used to assess the effectiveness of the 10-week /40-hr training program. Following the first survey, identified weaknesses in data quality and associated skill shortfalls were used to direct additional training in follow-up workshops. Two surveys of participants' thoughts and experiences were used to develop insights into program elements that effectively motivated and retained volunteer CS surveyors capable of producing reliable data. Survey data collected enables ongoing assessment of avian diversity and abundance and the impact of park management actions addressing identified threats within the vulnerable Stringybark Heathy Woodland in the GGNP (Parks Victoria, 2019). The results of the first autumn and spring 2021 surveys are reviewed.

Methods

To help foster a new younger cohort of competent bird surveyors, a key focus of the GGBS program was to incorporate, train and provide opportunities for relative novices.

Citizen science program implementation

Participant Selection

The program was advertised through social media, local radio, flyers and word of mouth. Under the survey protocol, the minimum number of participants required to deliver the program was 36. The program set out to involve 40 applicants, to enable pairs to monitor two sites in the planned seasonal (spring and autumn) surveillance program. Greenwood (2007) found that it is useful to assess the skills of potential participants and, rather than rejecting those thought not to have adequate skills, to provide training.

In response to the advertising program, prospective participants were asked to complete an online application form. Applicants were assessed against six selection criteria:

(1) Availability – must attend a 10-week (4 h/week) training program, a refresher workshop and the spring and autumn two-day monitoring weekends.
(2) Fitness – participants needed to work in remote areas, walking through woodland terrain on flat to moderate slopes for up to 4 h per day.
(3) Health – with remote bird surveys, timely medical assistance was not immediately available. Participants had to have no pre-existing injuries/illnesses that may require a timely or specialised medical response.
(4) Experience – previous participation in bird monitoring programs or remote area fieldwork was desirable but not mandatory.
(5) Equipment – access to clothing and outdoor gear enabling self-sufficiency for survey work in the field.
(6) Possession of a full driving licence: Volunteers were required to drive to and from the survey sites each day in their own vehicle. Many sites are adjacent unsealed roads, with some requiring four-wheel drive vehicles to traverse.

In the online portal, applicants addressed 15 questions, 10 of which related to these selection criteria. Availability, suitable fitness and health were non-negotiable for selection. Preference was given to people who lived locally and those more experienced in working or spending time in remote areas. Successful applicants were then asked to join the Parks Victoria *ParkConnect* portal.

Following successful completion of the first autumn surveys, a number of external factors affected volunteer availability – four of the original 39 trained citizen scientists were unable to commit to the spring survey weekend, being either unavailable due to COVID-19 lock downs in Melbourne or family commitments. Consequently, recruitment for new volunteers was necessary, with six full applications received. Four participated in the spring survey. Before the COVID-19 lockdown, 37 of the original 39 trained volunteers had confirmed their participation in the spring survey, but this declined to 30. With reduced participation, volunteers were asked to increase the number of surveys they completed. Three groups agreed to survey additional sites. One volunteer completed eight surveys to ensure a complete data set for the program.

Training program

Objectives. The initial objectives of the 10-week program were to provide sufficient knowledge and experience for citizen scientists to quickly and effectively identify most birds likely encountered by sight and/or call, to teach advanced identification skills where a bird can be identified without a clear sighting (e.g. using call, behaviour, habitat use, etc.), to provide training and experience in survey methods and to establish a specialist friendship group with expert members to facilitate ongoing learning and knowledge sharing.

Bird identification and survey skills. Two free 10-week bird identification and survey skills courses were offered – northern (Halls Gap) and southern Grampians (Dunkeld) – with each capped at 20 participants. The course was designed and tested prior to the start of this program, being run on 14 previous occasions by GK, with over 260 people having completed the program.

Nine of the ten 4-h training sessions (total 40 h) were based on a similar lesson design: Each week participants met in the field at a different habitat type for a 1-h walk in small groups identifying birds under the guidance of a skilled field ornithologist. They then returned to an indoor facility, for a one-hour talk on an area of specialist knowledge followed by 2 h of identification of birds using a field guide from photos in PowerPoint slides and call playback. Over the 9 weeks, participants were provided with a chance to identify most of the sexual, seasonal and age-related variations in plumage for nearly 300 species recorded across the southwestern region of Victoria. The setting enabled participants to work together, share knowledge, ask questions, learn how field guides are laid out and develop a baseline knowledge of species likely encountered in the region. Week 9 differed by having 2 h of practising three repeated 2-h/20-min surveys in pairs in the field. They then returned to the hall for training in Parks Victoria's volunteer OH&S requirements and an open question forum.

The program provided training on key characteristics of each bird family and their evolutionary relationships, bird identification practice using PowerPoint slides to enable effective use of field guides and the layout of field guides and bird apps to facilitate rapid identification. Participants were aided in the bulk purchase of modern up-to-date, best-practice field guides. Training was provided in bird topology, anatomy, feathers and colouration, plumage change with sex, age, feather deterioration, moult cycles, classification, bird song and call, bird behaviour, habitat use, survey techniques and equipment.

They were given extensive experience in field identification under expert guidance and class-based identification of birds with emphasis on alternative factors such as bird behaviour and social structure, local, seasonal and annual movement patterns, flight characteristics, habitat and microhabitat use and identification by call. Memory aids for identifying and remembering songs and calls were given and practiced. Guidance was given in deciding when a surveyor can and cannot identify a bird, and what to do if they cannot identify it. Technical advice on the use of binoculars and telescopes was given with an explanation of different types of binoculars and guidance on individual surveyor needs, as well as advice on and assistance with the purchase of appropriate equipment, and the use of audio recorders to record bird calls. Training was given in taking effective journal notes. Bird speciation and evolution were outlined. An explanation of and practical experience with protocols to survey birds, hints on effective data recording, explanation of different coordinate systems, the use of the mapping applications (Apps) (Avenza Maps® App – version 3.15.2 Build 15) and GPSs were given. Motivation and willingness of the observer to make identifications (Kepler & Scott, 1981) were taught or discussed to improve data quality. Finally, volunteers were given training in data entry and submission to a database (specifically, BirdLife Australia's Birdata App https://birdata.birdlife.org.au/) for storage and analysis in a GGBS login on the Birdata website.

During each 4-h session, participants were provided with handouts of key figures, electronic access to related published scientific literature and copies of PowerPoint talks and all bird photos to enable follow-up and revision at home, and guidance on how to make georeferenced maps using publicly available mapping sites (e.g. Mapshare https://mapshare.vic.gov.au/MapShareVic/).

Parks Victoria – Occupation Health and Safety (OH&S). Active involvement of a specialist community liaison park ranger (HA) to co-ordinate the volunteers, address all Parks Victoria *ParksConnect*, OH&S and reporting requirements, was critical in overcoming a potentially onerous load on volunteers and informing and liaising with management.

A field guide (Kerr & Auld, 2021) with details of each 2-ha survey site was provided to all CS surveyors. In addition to outlining the project, field safety and presurvey checklists, the guide provided a concise overview of how to reach each site, regional and site maps, outlined possible risks associated with a site (e.g. slope, scrub height and density), its vegetation cover and fire history. Participants were provided with georeferenced pdf maps showing an outline of the 2-ha site overlaid onto an aerial photo with nearby roads and tracks marked for use in Avenza maps when undertaking their survey. The Avenza Maps App allowed car location to be marked, and the tracking facility provided a "snail trail" of movement on the map facilitating return to the car.

On the Friday before the weekend of each season's (autumn and spring) surveys, participants were trained by HA to use Parks Victoria's trunk radios and GPS SPOT trackers® to enable report-in when at remote field sites during surveys. Participants were provided with Phytoclean® in spray bottles to address the threat of the spread of *Phytophthora cinnamomi* by surveyors and with first aid kits containing bandages for snake bites. Following difficulty in reporting in with trunk radios in autumn, all participants were given SPOT trackers in spring.

Evaluation of citizen scientist data. To cross-validate CS survey data and to help determine focal points for ongoing training, surveys at each site using the same protocol were undertaken by an experienced professional field ornithologist (GK), on either side of both the autumn and spring CS survey periods (four surveys in total, Table 1); GK has worked as a professional field ornithologist undertaking bird surveys across Australia for 20 years. He has undertaken over 400 2-ha/20-min surveys across the GGNP region since 2018. As is often typical of such professional work (Lindenmayer et al., 2014b) these surveys were funded by an unconnected series of small, short-term grants, tendered projects and philanthropy to address specific questions with no likelihood of continued funding into the future.

Refresher Workshop Prior to the Spring Survey. Prior to the spring GGBS weekend (Nov 2021), a workshop overviewed the outcomes of the first set of autumn surveys (Conducted in Apr 2021) and provided feedback on effective outcomes and areas that needed redressing following comparison with data from concurrent surveys by the professional field ornithologist. Based on this analysis, the group revised identification on songs and call for 16 species that were significantly under-reported in the autumn survey. Participants were then given a one-hour quiz in groups on bird calls. There was also an open forum to address any questions, concerns, or comments.

Monitoring protocols

Study area

The project study area was located within the GGNP in southwestern Victoria (Figure 1), with bird surveys undertaken at 36 pre-determined survey sites. These sites were originally established to examine mega-fire impact on fauna using the post-2006 wildfire landscape of the GGNP (Stevens et al., 2012). Sites were stratified within the National Park's red fox (*Vulpes vulpes*) poison baiting perimeter, within Heathy Woodland (EVC 48) and some areas of Sand Heathland (EVC 6) vegetation types, covering six categories of fire history. Subsequent prescribed burns and wildfires have confounded this original experimental design. All sites were below 470 m Australian Height Datum (AHD), located no closer than 2 km from another site, and within 300 m of a track or road. A feral cat (*Felis catus*) baiting program using 1185 Curiosity® was established in 2020 by Parks Victoria incorporating monitoring sites (Figure 1). The analysis of the potential fire history impact on bird diversity and abundance is reported elsewhere (Kerr & Gully, 2023).

Bird survey method

Both professional and CS surveys followed standardised surveys of bird counts based on either visual and/or auditory identification during a 20-min period as they walked

Table 1. Survey dates for the citizen scientist and professional Great Gariwerd Bird Survey.

Survey Number	Surveyor/s	Start Date	Finish Date	Surveillance Period	Number of surveys
1	Professional	13/04/2021	19/04/2021	Autumn 2021	36
2	GGBS Citizen Scientists	17/04/2021	18/04/2021	Autumn 2021	144
3	Professional	19/04/2021	24/04/2021	Autumn 2021	36
4	Professional	07/10/2021	13/10/2021	Spring 2021	36
5	GGBS Citizen Scientists	10/11/2021	23/11/2021	Spring 2021	144
6	Professional	11/11/2021	19/11/2021	Spring 2021	36

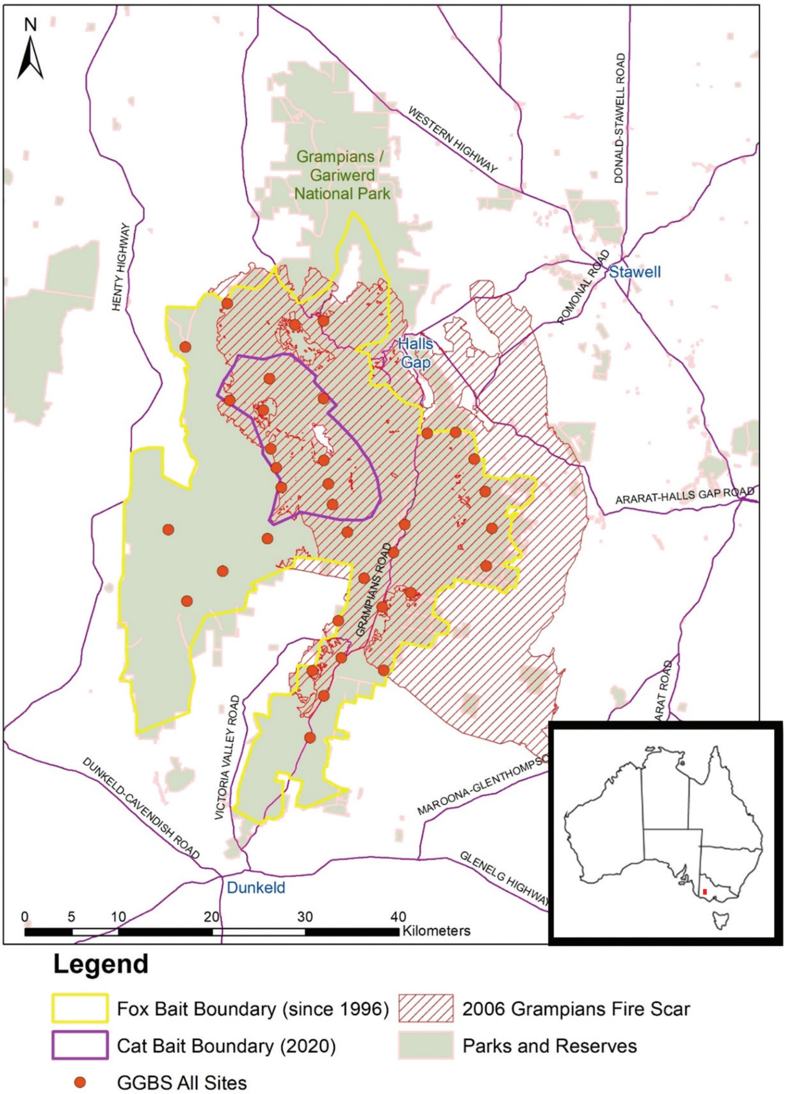

Figure 1. Locality map of the Grampians Gariwerd National Park study site, boundary for both the fox baiting program (which has been running annually since 1996) and the cat baiting program initiated in 2020 (Stevens et al., 2020), extent of the 2006 severe landscape-scale wildfire (mega fire), and distribution of all Great Gariwerd Bird Survey (GGBS) sites.

a similar path (Figure 2) around a 2-ha rectangular site (Field et al., 2002, 2004, 2005; Loyn, 1986), with counts constrained to birds detected in and above the two-hectare site. Surveyors needed to decide whether flying birds were occupying or using the survey site, e.g. birds of prey or swallows and martins foraging within or above the canopy, or birds moving between microhabitats within the site. Overhead transient birds, high above the site without an obvious ecological connection to the site, were not included in the count.

To enable a consistent survey approach in the medium to long term and to reduce the risk of pest or disease dispersal (e.g. *Phytophthora cinnamomi*) each 2-ha site

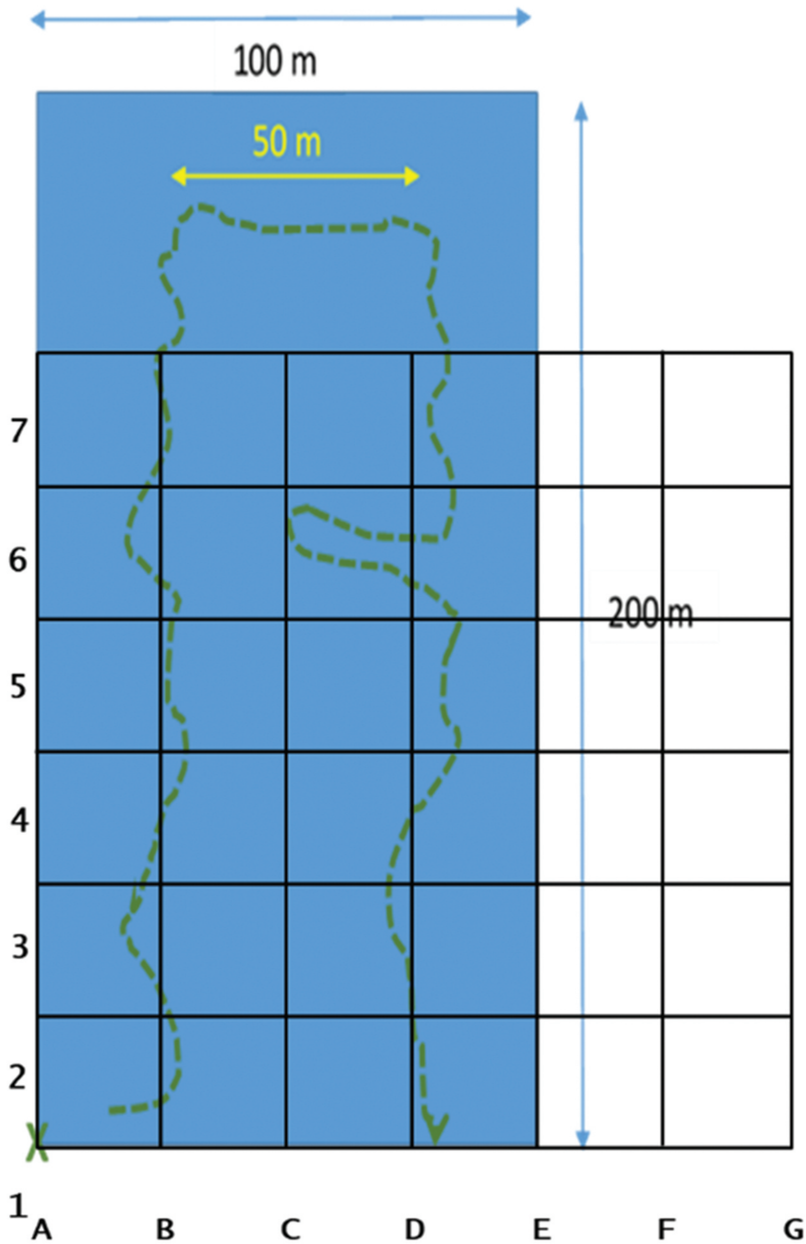

Figure 2. Relationship between the existing marked mammal survey quadrat (150 m × 150 m – 49 trap locations) and the 200 m × 100 m (2 ha) bird survey quadrat (blue rectangle).

(200 m × 100 m) was overlain onto an established 150 × 150 m mammal survey trap grid at each site (Figure 2).

All citizen scientists and the professional surveyor entered survey data via a GGBS login with password in the Birdlife Australia Birdata App (https://birdata.birdlife.org.au/) installed on their smartphone.

The CS surveyors were taught to follow a set survey protocol. At the A1 quadrat corner, surveyors filled in the "who, when, what and where" data within the Birdata App. The GGBS login contained the 36 sites as a mapped location with auto population of relevant site data fields (site name, site co-ordinates, date, time) to minimise data entry errors. Surveyors selected survey type from a drop-down menu. Because of their influence on bird detectability (Bibby et al., 2000), weather details, i.e. wind strength (calm, slight (leaves moving), moderate (canopy moving), strong (branches moving)), temperature (cold (0–10°C), mild (11–20°C), warm (21–30°C), hot (31–40°C)) and cloud cover (octets), were also recorded as notes in the Birdata App. A standardised route was followed as best they could across the 2-ha site (e.g. Figure 2). As they walked, they identified all birds detected within 25 m either side of the path walked.

To maintain consistency in habitat surveyed over time and to aid movement through denser habitat, surveyors could see their actual position within a defined boundary for each site on a georeferenced map in Avenza Maps.

The Birdata App requires bird name entry from drop-down menus and surveyors are notified and asked to provide supporting evidence if they select species not usually recorded in the region. At the completion of the survey only complete and reviewed data can be uploaded to Birdata.

Steps undertaken to minimise observational or recording survey errors by citizen scientists included:

- surveyors working in pairs (one recording, one navigating, both scanning for birds) to increase detection rates, limit the level of multitasking during the survey and enable sharing of knowledge and joint identification;
- constraining survey teams to a small number of sites (usually two) with the objective of enhancing familiarity with sites, freeing surveyors from focusing on navigation and increasing bird observation time;
- training to identify all 300+ bird species found across the region, but with a focus on the approximately 100 species recorded in stringybark woodlands;
- weekly one-hour field identification in groups of 10 in different habitats with a skilled trainer over the 10-week training program;
- weekly information given in PowerPoint slides and handouts made available in electronic format to enable follow-up learning and revision.
- facilitating each observer to obtain appropriate quality binoculars, field guides and e-guides to identify birds;
- requiring data entry and storage through Birdata App during the survey to minimise data entry and transcription errors;
- pairing of less experienced birders with those more skilled; and
- matching of fitness levels and physical capabilities with challenge of terrain and bush density at each site.

Survey frequency and timing

The GGBS was designed to run on one weekend in mid-autumn and one weekend in mid-spring each year. On both Saturday and Sunday, the citizen scientists undertook a survey at each site in both the morning (between 8 am and 11 am) and the afternoon (between 3 pm and

6 pm) to give four surveys/site in each of the autumn and spring surveillance periods. During the 4 days prior to and the 4 days following (weather permitting) the CS survey weekend, all sites were surveyed once by the professional field ornithologist (Table 1). Consequently, the 36 sites were visited four times by the citizen scientists and twice by the professional in a season. These two sets of surveys by the professional field ornithologist were designed so that each site was surveyed once in the morning and once on another day in the afternoon. The different-day repeats were implemented to capture significantly more species per unit of survey effort and yield a higher richness estimate (Field et al., 2002). This gave a total of 72 2-ha/20-min surveys by the professional and 144 by the citizen scientists in each of the autumn and spring surveillance periods.

In spring 2021, the planned survey weekend was cancelled following a COVID-19 outbreak in Halls Gap. Surveys by citizen scientist pairs were consequently spread out over two-weeks (10/11/2021 to 23/11/2021) at each group's discretion. Some citizen scientists were unable to participate due to lock downs in their hometowns. This meant there was a 3-week break between the first professional ecologist survey and the first CS survey, and the second professional ecologist survey was completed during the last week of the two-week CS survey period.

In addition to the standardised survey periods, these trained volunteers are also invited to conduct surveys at these sites on an *ad hoc* basis at other times throughout the year.

Statistical analysis

Analysis to estimate the number of bird species in the assemblage represented by the surveys was carried out using EstimateS Ver 9.1.0 (Colwell, 2013). Site-based species counts rarefaction curves were created using 100 randomisation runs with 1.5X extrapolation of rarefactions curves. Estimates were made at every data point. We used the classic formula for Chao 1, randomised individuals without replacement and calculated S_{est} (analytical), i.e. the expected number of species in t-pooled samples with lower and upper 95% confidence intervals. All six assumptions were met for sample-based rarefaction to be used rigorously to compare species richness in two or more samples or assemblages (Magurran & McGill, 2011).

An empirical cumulative distribution function (eCDF) was used to compare species abundance in each community between the professional ecologist and the CS surveys. This method corrects for different species diversities between communities allowing for valid comparisons between communities (McGill, 2011).

Pearson product moment correlation coefficient and linear regression were used to determine the levels of association between means of total species diversity in all surveys at each site between the professional ecologist and the citizen scientists and the means of total bird abundance in all surveys at each site between the professional ecologist and the citizen scientists.

A GLM repeated measures doubly multivariate design (SPSS v26 for IBM) was used to analyse the bird counts for the within site factors of surveyor (citizen scientists or professionals) for each surveillance period (autumn and spring) at each survey site. Two dependent measures were obtained for each site: the mean of the total species recorded in each survey and the mean of the total number of birds recorded in each survey during the surveillance period (professional two surveys, citizen scientists four surveys).

Results

Citizen scientists selection

Fifty-four full applications were received from across a broad region, with applicants living up to 260 km away from the GGNP (e.g. Melbourne, Torquay, Warrnambool, Portland, Horsham and Ararat). In the post-course survey, participants indicated they discovered the program via a wide variety of sources. Many (12 of 31) indicated they became aware of the program via word of mouth, eight via emails, and seven via social media. Only two heard of the program through advertisements and articles in the local papers and one through their local Landcare group. All bar two respondents were happy with the information available to them before applying. Satisfaction with the recruitment process was very high (mean = 4.55, sd = 0.62, scale 1 = not at all satisfied – 5 = very satisfied).

Applicant prior experience in bird watching/monitoring ranged from interested novices through to long-term experience in bird monitoring, with many working in the environmental field. Most applicants had moderate-to-high-level experience in four-wheel driving, 21% admitted to no experience, but all held a driver's licence. All had remote camping and bush walking experience and all bar one had previously volunteered to work on environmental or CS projects. Ages ranged from mid-20s to early 70s, with nearly 60% female, and 47.5% under the age of 40. Forty-eight per cent held current first aid certificates and certificates from a further 25% had recently lapsed.

Citizen scientists' experiences through the program

Survey 1: Bird course, OH&S training and autumn survey

Thirty-nine of the 40 people invited to participate completed the 10-week, 40-h training program. One participant withdrew after 4 weeks due to work and family commitments. Weekly attendance averaged 91.3% (se = 1.50%, $n = 10$ weeks). Where individuals missed a session, they were able to subsequently complete the workshop component at home, working through the PowerPoint slides and worksheets provided and visiting the field site. Total volunteer time was over 1560 h for the course, with drive time, extra study at home and field practise additional.

Thirty-one (77.5%) course participants completed the online survey following the autumn bird surveys. The survey sought to clarify experiences of the training program. Responses were scored from 1 – strongly disagree, to 5 – strongly agree. Participants were happy with the weekly emails providing details of the week ahead (mean score 4.74, sd = 0.44), with only three feeling there were times where more information was required. Weekly course information (PowerPoint slides and handouts) was shared with participants through both drop box and/or upload to a USB, with two participants finding drop box difficult to work in. Where a COVID-19 lockdown across Victoria resulted in a snap lockdown in the region, the program was delivered online for 1 week. Participants found this worked well and would have liked access to videos of other presentations to aid revision, but all found the face-to-face sessions most valuable. Suggestions regarding improvements to delivery focused on more time to be spent on bird calls (seven people), more emphasis on local species likely to be met in the surveys rather than across the region (three people), more practical experience in the field to complement the in-door activities (five people) and a greater emphasis on getting to know other participants and more opportunities to practice with them outside formal activities. Seventy-seven per cent felt nothing should be removed from the existing course, the remainder suggested some elements of theory be deleted and others felt the focus should be on birds likely to be encountered locally. All respondents would recommend the course to other volunteers. The timing of the course delivery (5 to 9 pm) was acceptable to all participants, but three commented on the suitability of mornings and weekends. Eight commented on the difficulty of getting away from work to be in the field by 5 pm. All respondents were happy with the weekly field trips, and satisfaction with the organisation of the weekly field course was very high (mean = 4.77, sd = 0.50).

Satisfaction with information provided for the survey weekend was generally very high (mean = 4.68, sd = 0.60), but two respondents indicated they were "uncertain". Satisfaction with the quality of instruction on the use of either radio or SPOT Tracker® to report in during the surveys was high, with 93.5% indicating the induction evening before the survey gave clear instruction. One person thought such training should occur earlier in the program. Fifty-two per cent felt that they would have been comfortable to conduct surveys without a call-in procedure, but the remainder saw it as important, particularly given the remoteness of some sites, the number of volunteers involved and, for some, the low level of field experience. Five respondents experienced initial difficulties during the field surveys in using Avenza Maps but were able to overcome these difficulties. Some suggested more training might have helped, but 84% felt they had no difficulties, and that training was adequate. Two had difficulty with the Birdata App, but 93.5% encountered no problems in the field. All bar one indicated that they would like to hear about future volunteering opportunities in the GGNP. Concluding comments on the program were made by 74%, and all were very positive particularly about both the training and the opportunity to participate in the survey program.

Survey 2: Refresher course and spring survey feedback

The spring refresher course was held in Dunkeld with two 4-h sessions delivered to 34 citizen scientists. Participation for some was not possible due to COVID-19 lock downs in their hometowns or family commitments.

Twenty-five people provided online feedback on the refresher course and their spring GGBS survey experiences. Three did not see value in attending a future refresher course, but 88% (22) found the content and presentations useful for their upcoming survey. All bar one would recommend the refresher course to others. The Parks Victoria pre-survey induction was seen to be important (Mean ± sd = 4.54 ± 0.59). All bar one respondent preferred the 10+ day window, rather than being constrained to one weekend, to complete their surveys.

Operation of the SPOT satellite trackers proved problematic for several groups and over half of the CS volunteers felt they led to more trouble. Two of the 15 groups failed to check in successfully, resulting in follow-up procedures, with Parks Victoria staff driving to their sites to confirm the safety and completion of the survey. Thirteen participants successfully used the devices during their survey with no complications.

When asked to self-analyse on improvements in identifications skills since the autumn survey and to identify any remaining areas of weakness, respondents indicated that they knew more birds and could identify more birds by call in the spring survey. But all indicated that there was a need to continue working on learning and applying bird calls for identification. Many noted the importance of the refresher workshop in identifying problematic species and the additional training on differentiating their calls.

Twenty-four of 25 respondents anticipated a return to the 2022 autumn survey, with three uncertain pending personal commitments. When asked about forming a management group to support logistics of upcoming surveys and program viability, nine volunteers indicated an interest. Four additional participants would be interested in the future.

Analysis of citizen scientist bird survey effectiveness

Data entry errors by citizen scientists were minor and related to 1. automated entry of the appropriate site location data into the BirdLife Australia Birdata App, through not waiting for the current position to be determined and the map to be updated, consequently selecting the incorrect site icon; 2. Failing to log out of a personal login for the Birdata App and then login to the GGBS login; and 3. Some surveyors did not always record the weather, i.e. wind, cloud, temperature or surveyor names in the notes field.

A two-way repeated measures analysis of variance (RMANOVA) compared both species richness and abundance of bird species recorded by the CS surveyors and the professional ecologist at each site. Data for each survey were aggregated to determine the mean total species richness and mean bird abundance at each site in each season (autumn and spring) for each observer group (Citizen Scientist and Professional). Using the Wilks' Lambda criterion, there was a significant effect for both Surveyor ($F_{2.34} = 288.426$, $p < 0.001$***) and Season ($F_{2.34} = 9.889$, $p < 0.001$***), but there was no significant interaction effect ($F_{2.34} = 1.020$, $p = 0.371$). The professional surveyor recorded on average significantly more species ($F_{1.35} = 21.968$. $p < 0.001$***) and significantly more birds ($F_{1.35} = 6.616$, $p = 0.015$*) at each site than the citizen scientist. There were significantly more species recorded on average in spring than autumn ($F_{1.35} = 15.440$, $p < 0.001$***, Figure 3(a)), but the mean number of birds recorded did not show a significant change between seasons ($F_{1.35} = 2.095$, $p = 0.157$, Figure 3(b)). The mean species diversity/survey and the mean total number of birds recorded in each survey were lower (Table 2) for the citizen scientists compared with the professional ecologist.

The citizen scientists recorded a higher overall diversity of birds during each surveillance period than the professional ecologist (Table 2). This is likely a product of the greater number of surveys undertaken by the citizen scientists (72 surveys/surveillance period professional, 144 CS). A rarefaction estimated species richness curve (Colwell, 2013), extrapolated to 1.5X the number of surveys in autumn for both the CS and the Professional data sets (Figure 4), shows that the observed species richness for the Professional data set follows the same trajectory and falls within the 95% CI of the larger CS data set, so the null hypothesis that there is no significant difference between the species richness' of the two samples is accepted (Simberloff, 1978). For both 1.5 X extrapolations of the Species Accumulation Curves (SAC), the species richness' are still climbing towards an asymptote, indicating that the number of surveys in the surveillance period did not fully define the avian diversity present.

A comparison of species recorded by CS surveyors and the professional highlighted a possible difference in skill levels and provided a key focus for the pre-spring surveillance workshop. During the autumn surveillance period, the CS surveyors recorded 17 species not

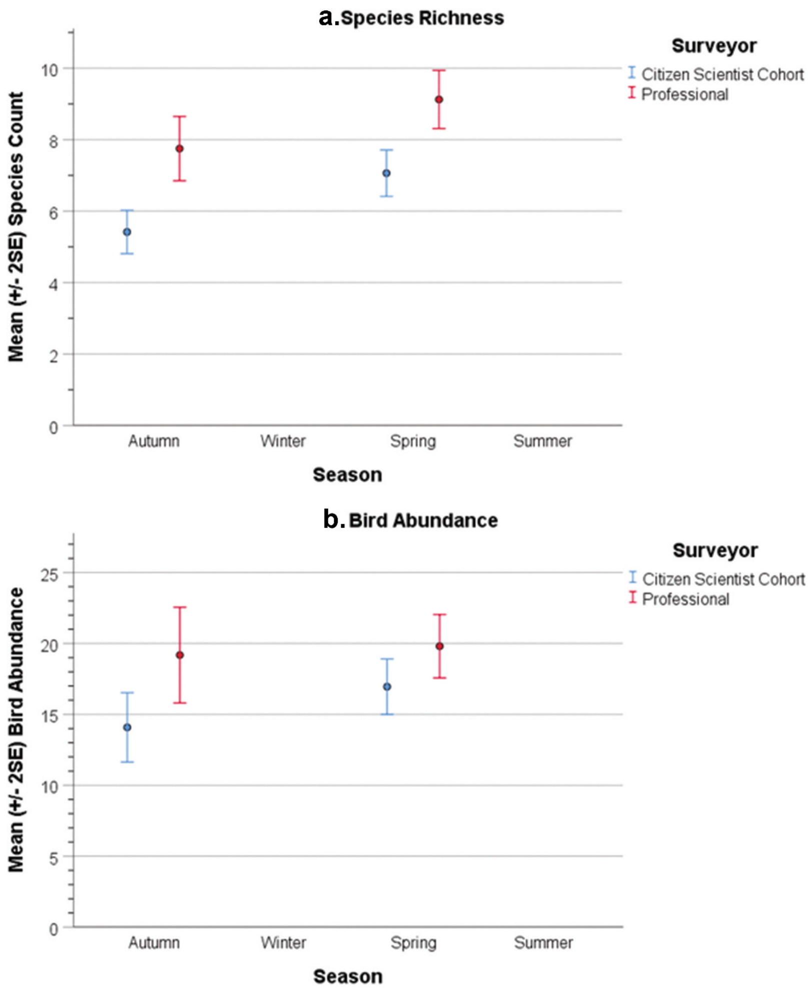

Figure 3. Comparison between survey outcomes for citizen scientists and professional for both mean species richness (top) and mean abundance (bottom) of bird species recorded in surveys in each season.

observed by the professional (Appendix 1). Ten of these species were singletons, and all bar one were rarely recorded by the professional ecologists in other surveillance periods and in low abundance, suggesting that this difference was the product of the citizen scientists undertaking twice the survey effort of the professional. Eight species were recorded by the professional and not the citizen scientists. Five of these were singletons and two were doubletons. The absence of the tawny-crowned honeyeater in the CS surveys and its presence in eight of the professional surveys suggested that this relatively unobtrusive and subtle calling species may have been missed by the CS surveyors. Forty-seven species were recorded by both the citizen scientists and the professional.

An eCDF comparison between CS and professional surveyors for the autumn surveillance period (Figure 5) showed two important contrasts:

Table 2. Comparison between concurrent citizen scientists and a professional field ornithologist seasonal survey bird species richness and abundance at each site.

		Autumn 2021					Spring 2021				
		Species richness			Abundance		Species richness			Abundance	
Surveyors	Number of surveys	Total species	Mean species/ survey	± SD	Mean total birds/ survey	± SD	Total species	Mean species/ survey	± SD	Mean total birds/ survey	± SD
Citizen Scientists	144 autumn 144 spring	68	5.42	3.644	14.08	14.674	83	7.06	3.894	16.95	11.728
Professional	72 autumn 72 spring	57	7.75	3.819	19.18	14.317	53	9.13	3.448	19.81	9.482

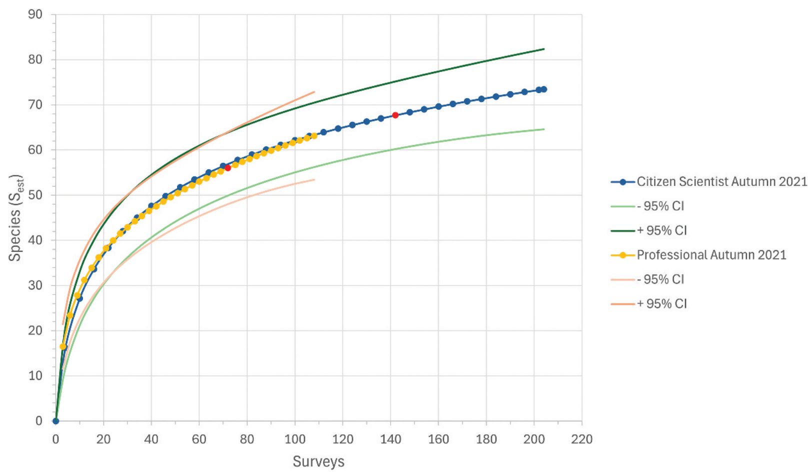

Figure 4. Rarefaction (S_{est}) comparison of citizen scientist and professional survey data species accumulation curves (with 95% confidence intervals). EstimateS Ver 9.1.0 (Colwell, 2013).

(1) There were approximately 12 of the more abundant species that were recorded less often by the citizen scientists than by the professional. This appears as a bulge in the orange line to the left on the eCDF graph on the top right.
(2) There were approximately 10 rarer species that were recorded at a relatively lower abundance by the citizen scientists than by the professional surveyor. These appear as a translation of the orange line to the left on the bottom left of the graph.

A Pearson's product-moment correlation coefficient was computed to assess the relationship between the proportion of surveys each species was recorded in by the citizen scientists and the professional ecologist. There was a strong positive correlation between the two variables in autumn, $r = 0.836$, $n = 116$, p (2-tailed) < 0.001***. This correlation increased in spring $r = 0.862$, $n = 116$, p (2-tailed) < 0.001***. This improvement may have arisen through increased citizen scientist survey experience following the first set of surveys and/or as the result of the workshop prior to the spring survey focussing on cryptic species and hard to recognise calls. Scatter plots summarise these results for the identified species (Figure 6). A Pearson's product-moment correlation coefficient was also computed to assess the relationship between the mean abundance/survey of each

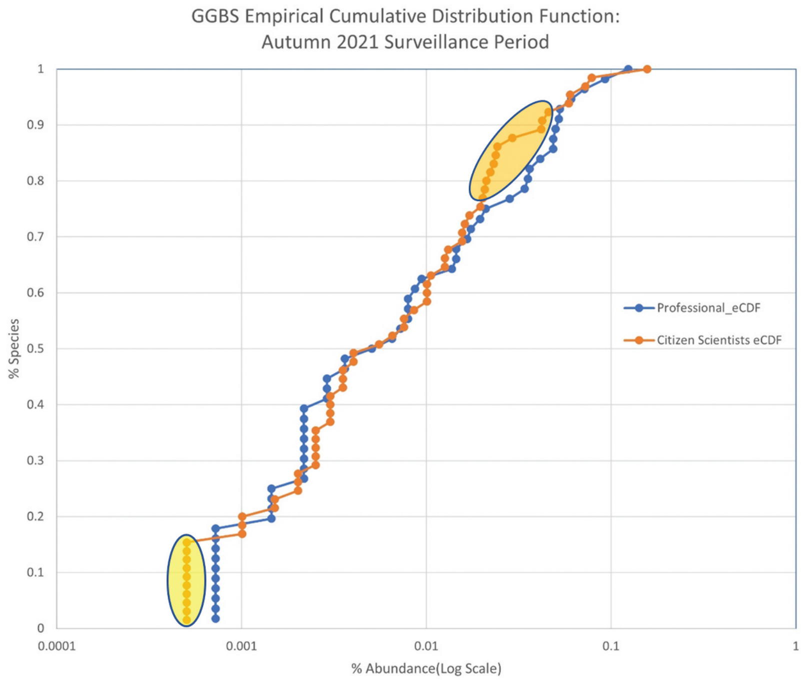

Figure 5. Empirical Cumulative Distribution Function (eCDF) comparison between citizen scientists and professional survey data for autumn 2021 surveillance period.

species recorded by the citizen scientists and the professional ecologist. There was a strong positive correlation between the two variables in autumn, $r = 0.768$, $n = 116$, p (2-tailed) < 0.001***. Again, this correlation increased in spring, $r = 0.797$, $n = 116$, p (2-tailed) < 0.001*** following the targeted workshop. Scatter plots summarise these results (Figure 7).

Discussion

This program sought to, and succeeded in, attracting, training and retaining a new cohort of skilled, independent bird surveyors to underpin a planned long-term CS program in the GGNP. Provision of a free, relatively comprehensive, 10-week course with a weekly commitment of over 4 h has proven to be highly attractive to a cross-section of the community. The program attracted a relatively young, gender-inclusive cohort that are under-represented in most of the birding and natural history clubs across the region. The high proportion of people from professional backgrounds was seen as an important component in the program's success. The general impression, based on post-course feedback, is that the course exceeded expectations, the combination of theory and practical information and experiences was highly appreciated and far more comprehensive than expected, taking the participant into new realms. People felt empowered to go away and continue learning. Overall people felt they came away with a good level of knowledge, but importantly they realised how much more there was to learn to carry out the surveys effectively, and they felt empowered

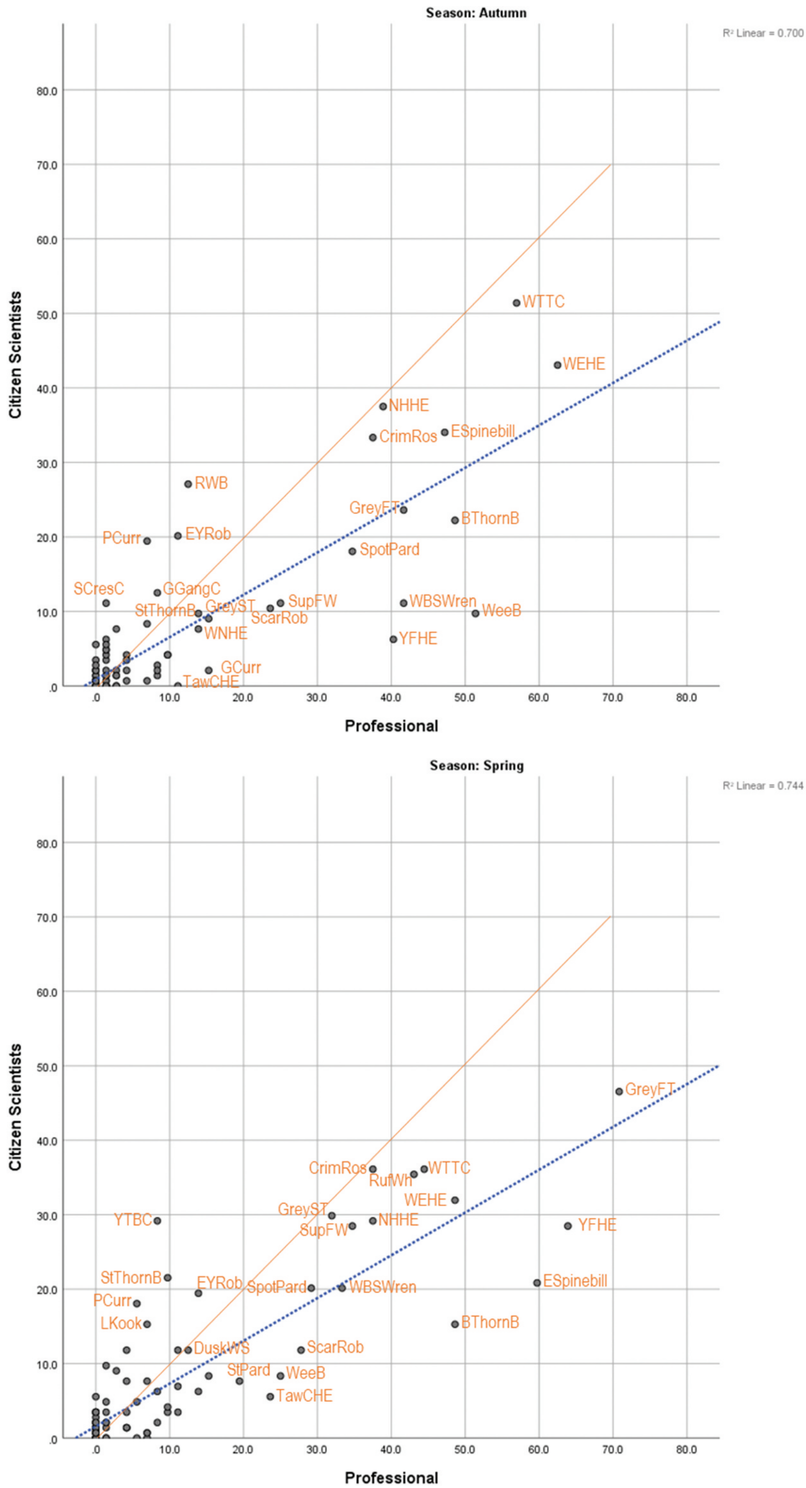

Figure 6. Comparison between citizen scientists and professional surveyors in species detection. Overall proportion of surveys each species was recorded in autumn (top) and spring (bottom). Orange line indicates line of equality. Blue dotted line is line of best fit. R^2 autumn = 0.700, R^2 spring = 0.744.

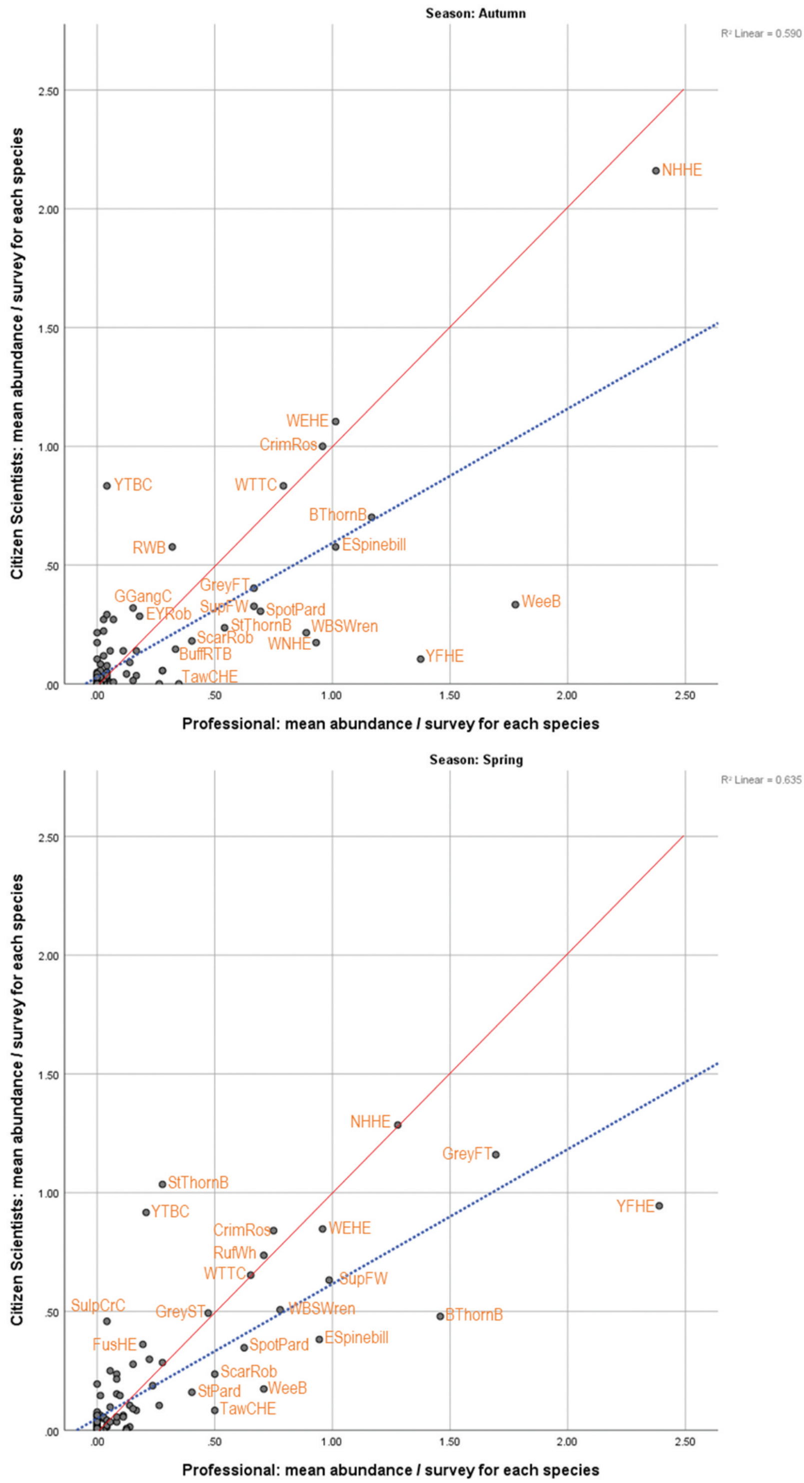

Figure 7. Comparison between citizen scientists and professional surveyors in mean species abundance/ survey. Mean abundance/survey for each species recorded in autumn (top) and spring (bottom). Red line indicates line of equality. Blue dotted line is line of best fit. R^2 autumn = 0.590, R^2 spring = 0.635.

to do this. This was particularly evident with the ubiquitous comment regarding the need for "more time spent on training people in bird calls". These outcomes reflect those reported in a systematic literature review of biodiversity CS projects (Peter et al., 2019) – with a gain in knowledge and changes in behaviour or attitudes most often recorded, but less often were the development of new skills, and increased self-efficacy and interest.

The pedagogical challenge of how to incorporate more effective learning techniques to facilitate the assimilation of the variety of calls and songs needed to identify species is ongoing. Creating time in an already overloaded 40-h program without missing other skills is the challenge. Pre-course review comments by birding specialists that the 40-h program appeared excessive have not been supported by the course participants.

An important element of the 10-week program was the provision of a variety of medium- to high-quality brands and models of binoculars for participants to try over the program. Training in the properties of different types of binoculars, an emphasis on the pros and cons of such factors as different magnifications, objective lens sizes and lens coating quality meant that people could select equipment appropriate to their personal characteristics, needs and budget. Facilitation in the purchase of binoculars, and the latest and best field guides, and e-guides during the course meant that nearly all participants came away with high-quality equipment and the training to use it effectively.

Training in the use of the Avenza Maps App and the Birdata App was necessary for program success and as noted in other studies (e.g. Fraisl et al., 2022) increased the quality of data captured. The use of the Birdata App is intuitively easy, particularly with initial guidance, and the use of dropdown menus avoids most forms of data entry errors. However, the registration process and login for the App are for many challenging, and hands-on guidance over several sessions was important to minimise problems. Many course participants had trouble in the effective use of Global Positioning Systems (GPSs) devices. The Avenza Maps App overcame the difficulty of working with either eastings and northings or latitudes and longitudes. The ability to create georeferenced maps at a variety of scales and load them into Avenza Maps enabled site location and made it relatively easy for citizen scientists to negotiate at times heavy vegetation in difficult terrain across the two-hectare area with minimal distraction. Training teams of two to work together to carry out the 2-ha/20-min surveys, with each person concentrating on either the navigation or data entry task, freed them to spend most of their time locating and identifying birds.

Volunteer retention can be a problem for CS practitioners (Adler et al., 2020). Retention of the trained CS observers is critical, as resultant increased survey species accumulation rates, particularly of harder to identify bird species, with continued participation, is intuitively expected (Kelling et al., 2015). Evidence to date indicates that this program has been successful in training and retaining a competent cohort of bird surveyors that are actively engaged and committed to fine tuning their identification and survey skills. Three years after the program started, approximately one-quarter of the trained citizen scientists have moved out of the region. A third course for 20 participants was run in spring 2023 to replace those lost. The importance of providing a positive supportive environment to enhance ongoing participation and to benefit from the concomitant improvements in data quality cannot be over-emphasised. Communication regarding all elements of the program was a key priority. The citizen scientists were actively engaged through weekly emails and social media to provide them with up-to-date information, maps and feedback opportunities. Wolcott et al. (2008) found that long-term volunteers stopped participating in surveys due to poor information dissemination and poor co-ordination of the surveys. They noted that other respondents cited transport issues and costs as reasons for cessation.

In this project, the importance of early planning and confirmation of key dates and their incorporation into the busy schedules of the citizen scientists was apparent when the spring survey was deferred due to COVID-19 community impacts, an impact on park programs seen across the world (Waithaka et al., 2021). Nearly one-quarter of the citizen scientists were consequently unable to fit the new dates into their schedules, necessitating additional surveys by some individuals. Importantly, Field et al. (2002) found the time-span over which different-day surveys are conducted within a season did not have a significant influence on species richness estimates, evincing a qualitative advantage to surveying on different days, regardless of the spacing of repeat visit.

Building a community and creating ongoing opportunities to develop skills were an important component of this project, but this represents a poorly studied element of CS programs (Adler et al., 2020). Following the completion of the first autumn survey, a celebratory dinner was held. Thirty-eight of the citizen scientists attended along with four higher-level park management staff. The opportunity to debrief, discuss the joys and challenges of the survey weekend with colleagues, facilitators and the Park staff was fundamental to resolving doubts and encouraging anticipation of the spring survey to come. Management was able to appreciate the positive energy and commitment of the citizen scientists and evaluate their knowledge and experience. Participants were active in the formation of small groups that worked to share knowledge and implement joint field trips to develop identification skills.

Tulloch et al. (2013) identified eight unique objectives for gathering and using volunteer-collected monitoring data. The GGBS program addressed all of these, i.e. inform management, increase public awareness, educate public on ecological issues, uncover serendipitous events, achieve community wellbeing through recreation in the natural environment, enable social and economic research, enhance ecological knowledge and improve monitoring and evaluation.

A critical component in the ongoing success of this program has been the involvement of a GGNP park ranger who specialises in enabling volunteer activity within the park to oversee both the organisation of, and communication with, volunteers and to ensure that existing Parks Victoria Volunteer and OH&S protocols are maintained. The role was also fundamental to maintaining effective communication between management, volunteers and the trainer, ensuring that the surveys were collecting data relevant to the management programs taking place in the park, providing feedback to management that links the data obtained with outcomes and funding programs, and actively working to incorporate the program into future planning for the park. The role of a scientist in the analysis and production of peer-reviewed papers for publication, assessment of the quality of data collected and analysis of data to address the key questions for the monitoring program have been fundamental to informing management, enhancing ecological knowledge and improving monitoring and evaluation. Media events associated with attracting participants and reporting on program outcomes, inclusion of ecological and behavioural theory and examples in the 10-week course and the analysis of data and reporting back to the citizen scientists have led to both increased public awareness and education opportunities. This has been particularly evident through the use by the citizen scientists of the PowerPoint slides from the weekly classes at home to teach family and friends about the course content. Through establishing a group-wide login in the Birdata App, the citizen scientists can access the data set they collected.

As was observed in this study, both McLaren and Cadman (1999) and Hanowski and Niemi (1995) noted that novice or less experienced observers tended to count fewer birds of most target species than the experienced observer when using song or call. The challenge of learning and being able to use bird call and song to identify the species encountered in the GGBS was recognised by the citizen scientists early in the 10-week bird course. Analysis of discrepancies between the professional ecologist's detection of species and birds and that of the citizen scientists verified the conclusions drawn by many of the citizen scientists on the need to improve their call identification skills following completion of the autumn surveys. Identification of problematic species and a renewed focus on their calls, behaviour and microhabitat use during the pre-spring survey workshop did improve species identification by citizen scientists in the subsequent spring survey.

The program has been effective in rapidly developing bird identification skills in participants. The evidence to date indicates that those who have been through the program have been fast-tracked across a major knowledge gap typically experienced by many birders as they accumulate knowledge on an *ad hoc* basis. But continued improvement and fine-tuning of skills with practice can be anticipated. At present, no method of adjusting bird count data to address bias appears to be effective for large-scale, multi-species monitoring surveys (Johnson, 2008). Johnson (2008) recommended that users of any method should recognise that variability in detectability influences the results. This suggests that researchers should attempt to remove as much of that variability as is reasonable by design control (e.g. by restricting counts of birds to certain calendar periods and times of day). An index is defined to be a variable that correlates strongly with abundance or density of a species in an area (Caughley, 1977). For indices to serve in a monitoring situation, all that is needed is that the variation in detectability be substantially less than the variation in population size sought to be detected and that it be independent of population size (Johnson, 2008). Maintaining the current survey methodology and timing will aid this outcome, while the CS surveyors continue to improve their skills over the following few surveys.

Given the anticipated natural attrition of the citizen scientists trained in this program over time, the need to initiate ongoing annual or biennial 10-week training courses to maintain a working core of 40 surveyors is apparent. Critical to the long-term success of the program will be an active effort to engage the current cohort of citizen scientists in training and supporting successive cohorts (Adler et al., 2020). The opportunity for the first cohort to pass on knowledge being as important as the need to work to maintain and improve their own.

Conclusion

This project has shown that an effective landscape scale CS bird monitoring program can be implemented using interested and motivated community members who participate in a 40-h training program. While initial survey outcomes were good, follow-up data analysis and workshops to address identified shortfalls further enhanced subsequent survey effectiveness. Importantly, the program design was attractive to participants, achieving a very high participation and retention rate, which added a significant number of skilled and developing bird monitoring practitioners active in the region.

Acknowledgments

The project received grant funding from the Australian Government through the Australian Heritage Grants Program and was funded with the support of the Victorian Government's Weeds and Pests on Public Land program and is helping to ensure that Victoria's natural environment is healthy, valued and actively cared for. BirdLife Australia provided support through their Birdata App and through access to the final data set. We thank Parks Victoria for supporting this project's implementation in the Grampians/Gariwerd National Park and for on-ground and logistical support through the Friends of Parks program. Finally, it has only been possible through the substantive generosity in thousands of volunteer hours and associated costs provided by 45 skilled and dedicated community members from across western Victoria who participated in a 10-week training program and undertook two sets of four surveys at 36 remote sites across the Grampian/Gariwerd National Park.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the Commonwealth of Australia [Australian Heritage Grant (AHG81062)]; Government of Victoria [Weeds and Pests on Public Land program]; State Government of Victoria.

ORCID

Gregory D. Kerr http://orcid.org/0009-0007-2765-4281

References

Abolafya, M., Onmuş, O., Şekercioğlu, Ç. H., & Bilgin, R. (2013). Using citizen science data to model the distributions of common songbirds of Turkey under different global climatic change scenarios. *PLOS ONE*, *8*(7), e68037. https://doi.org/10.1371/journal.pone.0068037

Adler, F. R., Green, A. M., & Şekercioğlu, Ç. H. (2020). Citizen science in ecology: A place for humans in nature. *Annals of the New York Academy of Sciences*, *1469*(1), 52–64. https://doi.org/10.1111/nyas.14340

Antos, M. J., Weston, M. A., & Priest, B. (2006). Factors influencing awareness of community-based shorebird conservation projects in Australia. *Applied Environmental Education and Communication*, *5*(1), 63–72. https://doi.org/10.1080/15330150500452398

Bart, J. (1985). Causes of recording errors in singing bird surveys. *Wilson Bulletin*, *97*(2), 161–172.

Bibby, C. J., Burgess, N. D., Hill, D. A., & Mustoe, S. (2000). *Bird Census Techniques* (2nd ed.). Academic Press.

Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V., & Shirk, J. (2009). Citizen Science: A developing tool for expanding science knowledge and scientific literacy. *BioScience*, *59*(11), 977–984. https://doi.org/10.1525/bio.2009.59.11.9

Caughley, G. C. (1977). *Analysis of Vertebrate Populations*. John Wiley and Sons.

Colwell, R. K. (2013). *EstimateS: Statistical estimation of species richness and shared species from samples*. Version 9.1.0 User's guide and application published at http://purl.oclc.org/estimates

Conrad, C. C., & Hilchey, K. G. (2011). A review of citizen science and community-based environmental monitoring: Issues and opportunities. *Environmental Monitoring and Assessment*, *176*(1–4), 273–291. https://doi.org/10.1007/s10661-010-1582-5

Farmer, R. G., Lenoard, M. L., & Horn, A. G. (2012). Observer effect and avian-call-count survey quality: Rare-species biases and overconfidence. *The Auk*, *129*(1), 76–86. https://doi.org/10.1525/auk.2012.11129

Field, S. A., Tyre, A. J., & Possingham, H. P. (2002). Estimating bird species richness: How should repeat surveys be organized in time? *Austral Ecology*, *27*(6), 624–629. https://doi.org/10.1046/j.1442-9993.2002.01223.x

Field, S. A., Tyre, A. J., & Possingham, H. P. (2005). Optimizing allocation of monitoring effort under economic and observational constraints. *The Journal of Wildlife Management*, *69*(2), 473–482. https://doi.org/10.2193/0022-541X(2005)069[0473:OAOMEU]2.0.CO;2

Field, S. A., Tyre, A. J., Rhodes, J. M., Jonzen, N., & Possingham, H. P. (2004). Minimizing the cost of environmental management decision by optimizing statistical thresholds. *Ecological Letters*, *7*(8), 669–675. https://doi.org/10.1111/j.1461-0248.2004.00625.x

Fraisl, D., Hager, G., Bedessem, B., Gold, M., Hsing, P.-Y., Danielsen, F., Hitchcock, C. B., Hulbert, J. M., Piera, J., Spiers, H., Thiel, M., & Haklay, M. (2022). Citizen science in environmental and ecological sciences. *Nature Reviews Methods Primers*, *2*(1), 1–20. https://doi.org/10.1038/s43586-022-00144-4

Greenwood, J. J. D. (2007). Citizens, science and bird conservation. *Journal of Ornithology*, *148* (**Suppl.** 1), S77–S124. https://doi.org/10.1007/s10336-007-0239-9

Hanowski, J. M., & Niemi, G. J. (1995). *Experimental design considerations for establishing an off-road, habitat-specific bird monitoring program using point-counts. USDA Forest Service Gen. Tech. Rep*. pSW-GTR–149.

Horns, J. J., Adler, F. R., & Şekercioğlu, Ç. H. (2018). Using opportunistic citizen science data to estimate avian population trends. *Biological Conservation*, *221*, 151–159. https://doi.org/10.1016/j.biocon.2018.02.027

Jarvis, R. M., Breen, B. B., Krageloh, C. U., & Billington, D. R. (2015). Citizen science and the power of public participation in marine spatial planning. *Marine Policy*, *57*(C), 21–26. https://doi.org/10.1016/j.marpol.2015.03.011

Johnson, D. H. (2008). In defense of indices: The case of bird surveys. *The Journal of Wildlife Management*, *72*(4), 857–868. https://doi.org/10.2193/2007-294

Kelling, S., Johnston, A., Hochachka, W. M., Iliff, M., Fink, D., Gerbracht, J., Lagoze, C., La Sorte, F. A., Moore, T., Wiggins, A., Wong, W.-K., Wood, C., Yu, J., & Goffredo, S. (2015). Can observation skills of citizen scientists be estimated using species accumulation curves? *PLOS ONE*, *10*(10), e0139600. https://doi.org/10.1371/journal.pone.0139600

Kepler, C. B., & Scott, J. M. (1981). Reducing bird count variability by training observers. *Studies in Avian Biology*, *6*, 366–371.

Kerr, G. D., & Auld, H. (2021). *Great Gariwerd Bird Survey – citizen science program field guide*. Nature Glenelg Trust, Mount Gambier. March 2021.

Kerr, G. D., & Gully, G. A. (2023). Bird communities and effects of management in heathy woodlands in the Grampians/Gariwerd National Park. *Transactions of the Royal Society of South Australia*, *147*(2), 230–267. https://doi.org/10.1080/03721426.2023.2265638

Lindenmayer, D. B., Burns, E. L., Thurgate, N., & Lowe, A. J. (Eds.). (2014a). *Biodiversity and environmental change: Monitoring, challenges and direction*. CSIRO Publishing.

Lindenmayer, D. B., Burns, E. L., Thurgate, N., & Lowe, A. J. (Eds.). (2014b). The value of long-term research and how to design effective ecological research and monitoring. *Biodiversity and environmental change: Monitoring, Challenges and Direction* (pp. 21–48). CSIRO Publishing.

Loyn, R. H. (1986). The 20 minute search – a simple method for counting forest birds. *Corella*, *10*(2), 58–60. https://doi.org/10.1111/j.1442-9993.2009

Magurran, A. E., & McGill, B. J. (2011). *Biological Diversity Frontiers in Measurement and Assessment*. Oxford University Press.

McGill, B. J. (2011). Species abundance distributions. In A. E. Magurran & B. J. McGill (Eds.), *Biological Diversity: Frontiers in Measurement and Assessment* (pp. 105–122). Oxford University Press.

McLaren, M. A., & Cadman, M. D. (1999). Can novice volunteers provide credible data for bird surveys requiring song identification? *Journal of Field Ornithology*, *70*(4), 481–490.

Neate-Clegg, M. H., Jones, S. E., Burdekin, O., Jocque, M., & Şekercioğlu, Ç. H. (2018). Elevational changes in the avian community of a Mesoamerican cloud forest park. *Biotropica*, *50*(5), 805–815. https://doi.org/10.1111/btp.12596

Parks Victoria. (2019). *Conservation action plan for parks and reserves managed by Parks Victoria. Grampians (Gariwerd)*. Parks Victoria.

Peter, M., Diekötter, T., & Kremer, K. (2019). Participant outcomes of biodiversity citizen science projects: A systematic literature review. *Sustainability*, *11*(10), 2780–2798. https://doi.org/10.3390/su11102780

Randler, C., & Bogner, F. (2002). Comparing methods of instruction using bird species identification skills as indicators. *Journal of Biological Education*, *36*(4), 181–188. https://doi.org/10.1080/00219266.00212002.09655830

Simberloff, D. (1978). Use of rarefaction and related methods in ecology. In K. L. Dickson & J. Cairns, & R. J. Livingston (Eds.), *Biological data in water pollution assessment: Quantitative and Statistical analyses* (pp. 150–165). American Society for Testing and Materials.

Stevens, M., Sandow, D., Sortino, D., Hanson, M., Russell, J., & Rodriguez-Malagon, M. (2020). *Use of curiosity baits to control feral cats in the Grampians National Park*. Parks Victoria, Gariwerd Environment and Heritage Team.

Stevens, M., White, J., & Cooke, R. (2012). Short-term impact of a mega-fire on small mammal communities during prolonged drought. *Proceedings of the Royal Society of Victoria*, *124*(1), 61–71. https://doi.org/10.1071/RS12061

Szabo, J. K., Fuller, R. A., & Possingham, H. P. (2012). A comparison of estimates of relative abundance from a weakly structured mass-participation bird atlas survey and a robustly designed monitoring scheme. *The Ibis*, *154*(3), 468–479. https://doi.org/10.1111/j.1474-919X.2012.01229.x

Tewksbury, J. J., Anderson, J. B., Bakker, J. D., Billo, T. J., Dunwiddie, P. W., Groom, M. J., Hampton, S. E., Herman, S. G., Levey, D. J., Machnicki, N. J., Martinez Del Rio, C., Power, M. E., Rowell, K., Salomon, A. K., Stacey, L., Trombulak, S. C., & Wheeler, T. A. (2014). Natural history's place in science and society. *BioScience*, *64*(4), 300–310. https://doi.org/10.1093/biosci/biu032

Tulloch, A. I. T., Possingham, H. P., Josep, L. N., Szabo, J., & Martin, T. G. (2013). Realising the full potential of citizen science monitoring programs. *Biological Conservation*, *165*, 128–138. https://doi.org/10.1016/j.biocon.2013.05.025

Waithaka, J., Dudley, N., Álvarez, M., Arguedas Mora, S., Fitzsimons, P., Figgis, J., Kim, S., Gallon, M., Pasha, M. K. S., Sierra, S., Valverde, P., Perkin, C., Roig-Boixeda, A., Wong, M., Valverde, A., & Wong, M. (2021). Impacts of COVID-19 on protected and conserved areas: A global overview and regional perspectives. *Parks*, *Special Issue*(27), 41–56. https://doi.org/10.2305/IUCN.CH.2021.PARKS-2327-SIJW.en

Weston, M., Fendley, M., Jewell, R., Satchell, M., & Tzaros, C. (2003). Volunteers in bird conservation: Insights from the Australian threatened bird network. *Ecological Management & Restoration*, *4*(3), 205–211. https://doi.org/10.1046/j.1442-8903.2003.00169.x

Wolcott, I., Ingwersen, D., Weston, M. A., & Tzaros, C. (2008). Sustainability of a long-term volunteer-based bird monitoring program: Recruitment, retention and attrition. *Australian Journal on Volunteering*, *13*(1), 48–53. https://doi.org/10.3316/ielapa.237154179197400

Appendix 1: Comparison of species recorded in all surveys during the Autumn surveillance period

	GK Present	Citizen Scientists Present	Both
GK No record		Australian Magpie, Brown Treecreeper, Crested Shrike-tit, Emu, Galah, Gilbert's Whistler, Long-billed Corella, Mistletoebird, Musk Lorikeet, Peregrine Falcon, Silvereye, Speckled Warbler, Stubble Quail, Swift Parrot, Whistling Kite, White-plumed Honeyeater, Yellow-tufted Honeyeater. **= 17 Species**	Australian Raven, Hooded Robin, Restless Flycatcher, Wedge-tailed Eagle, White-browed Babbler, Dusky Woodswallow, Fuscous Honeyeater, Rufous Whistler, Sulphur-crested Cockatoo, Black-faced Cuckoo-shrike, Golden Whistler, Laughing Kookaburra, Striated Fieldwren, Tree Martin, Yellow Thornbill, Yellow-tailed Black Cockatoo, Common Bronzewing, Welcome Swallow, Little Raven, Pied Currawong, Forest Raven, Striated Pardalote, Little Wattlebird, Gang-gang cockatoo, Grey Shrike-thrush, Southern Emu-wren, Grey Currawong, Eastern Yellow Robin, Brown-headed Honeyeater, Crescent, Honeyeater, Red Wattlebird, Buff-rumped Thornbill, Scarlet Robin, Striated Thornbill, Grey Fantail, Superb Fairywren, Spotted Pardalote, White-throated Treecreeper, White-browed Scrubwren, White-naped Honeyeater, Crimson Rosella, White-eared Honeyeater, Eastern Spinebill, Brown Thornbill, Yellow-faced Honeyeater, Weebill. **= 47 Species**
Citizen Scientists No record	Bassian Thrush, Brown Goshawk, Collared Sparrowhawk, Common Blackbird, **Tawny-crowned Honeyeater, Varied Sitella**, Little Corella, **Chestnut-rumped Heathwren**. **= 8 Species**		