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Journal
Australian Journal of Zoology, 68(6)

ISSN
0004-959X

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Publication Date
2020

DOI
10.1071/zo20051

Peer reviewed

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Source: Australian Journal of Zoology, 68(6) : 364-381

Published By: CSIRO Publishing

URL: https://doi.org/10.1071/ZO20051

CSIRO PUBLISHING

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https://doi.org/10.1071/ZO20051

Citizen science implements the first intensive acoustics-based survey of insectivorous bat species across the Murray–Darling Basin of South Australia

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Abstract. Effective land management and biodiversity conservation policy relies on good records of native species occurrence and habitat association, but for many animal groups these data are inadequate. In the Murray–Darling Basin (MDB), the most environmentally and economically important catchment in Australia, knowledge gaps exist on the occurrence and habitat associations of insectivorous bat species. We relied on the interest and effort of citizen scientists to assist with the most intensive insectivorous bat survey ever undertaken in the MDB region of South Australia. We used an existing network of Natural Resource Management groups to connect interested citizens and build on historical observations of bat species using a fleet of 30 Anabat Swift bat detectors. The survey effort more than doubled the number of bat occurrence records for the area in two years (3000 records; cf. 2693 records between 1890 and 2018; freely available through the Atlas of Living Australia). We used multinomial logistic regression to look at the relationship between three types of environmental covariates: flight space, nearest open water source and vegetation type. There were no differences in species richness among the environmental covariates. The records have been, and will continue to be, used to inform government land management policy, more accurately predict the impact of development proposals on bat populations, and update conservation assessments for microbat species. A social survey tool also showed that participation in the project led to positive behaviours, and planned positive behaviours, for improving bat habitat on private land.

Keywords: Anabat, bat detector, BioCollect, echolocation, database, distribution, community science, Murray–Darling Basin.

Received 15 June 2020, accepted 14 September 2021, published online 6 October 2021

Introduction

Bats have not experienced the same conspicuous and drastic declines from feral predators and habitat change and loss as some other Australian mammals (Burbidge *et al*. 2008; although see Richards and Woodside 2018; Woinarski 2018; Ratnayake *et al*. 2019). This helps to explain the relative lack of attention given to bats by biologists. As a consequence, less information is available on them relative to other vertebrate groups, and little understanding exists of their response to habitat changes. For example, when estimating wildlife mortality rates from the catastrophic bushfires of summer 2019–2020 in south-eastern Australia (University of Sydney 2020; Woinarski *et al*. 2020), bats were excluded because no information was available on the density of the 37 bat species of the region (Johnson *et al*. 2007).

Bats are indeed sensitive to changes in their environment. The removal of tropical forest results in a decline of bat species that forage within the forest interior (Jones *et al*. 2003). Some bat species that occupy forests in eastern Australia also respond negatively to forest fragmentation and isolation (Law *et al*. 1999). In the largest and most environmentally and economically important catchment of Australia, the Murray–Darling Basin (MDB), bat diversity is greater in the floodplain mosaic than in the adjacent dry vegetation and agricultural lands (Lentini *et al*. 2012; Blakey *et al*. 2017). Floodplain habitats include rivers, lakes, vegetated wetlands, floodplain forests, and floodplain woodlands. However, in the past 110 years, the construction of dams and extraction of water for irrigation has drastically changed flood duration, extent, frequency and seasonality in the MDB, leading to a pattern of ecological decline (Kingsford 2000; MacNally *et al*. 2011; Kingsford *et al*. 2015). The consequences of anthropogenically altered flow regimes have been exacerbated by drought, especially the South East Australian Millennium Drought of 2000–2009 and subsequent La Niña floods, and include changes in floodplain vegetation communities (Colloff *et al*. 2015; Wang *et al*. 2018), soil chemistry (Mosley *et al*. 2014), increased dryland salinity (Heimhuber *et al*. 2019), mass fish mortality events (Vertessy *et al*. 2019), and a predicted decline in birds (McGinness *et al*. 2010). Because bats have a lower reproductive output than many other vertebrates (Barclay and Harder 2006), they may be slower to adapt to changes in the quality of their floodplain habitats that result from fluctuations in river flows, drought and changing climate. Without ongoing collection of information in the MDB on what a significant proportion of the mammal fauna (i.e. bats) might be experiencing, there is diminished opportunity to include them in management and conservation planning.

The 640 km South Australian portion of the Murray River, from the Victorian border to the Southern Ocean (or 'Murray mouth'), supports 18 bat species (Churchill 2008). Four of these species are listed as Endangered and one as Vulnerable under state legislation (*National Parks and Wildlife Act 1972*; *NPW Act 1972*), and one is also listed as Vulnerable under national legislation (*Environment Protection and Biodiversity Conservation Act 1999*; *EPBC Act 1999*). Periodic reassessment of their conservation status by the South Australia Government's Department for Environment and Water (DEW) is limited by an almost complete lack of recent data on species occurrence. Recovery efforts for the Critically Endangered (*EPBC Act 1999*) southern bent-winged bat (*Miniopterus orianae bassanii*) are the exception (Kerr and Bonifacio 2009; NGT 2014; Lumsden and Jemison 2015; Thompson 2018). Scant resources have been dedicated to other insectivorous bat surveys and management, despite the objectives of DEW and Natural Resources South Australian Murray–Darling Basin (NR SAMDB; now Landscape SA) around resilience of native ecosystems. The difficulties of conducting monitoring of volant nocturnal bat species over vast and remote areas must be acknowledged. Clearly, novel ways to implement and manage monitoring efforts need to be explored.

A citizen science (or community science) approach involves scientists cooperating with the community to conduct scientific research and environmental monitoring. It can be an effective approach for studying species over large geographic scales, including on private land, when resources are limited (Dickinson *et al*. 2010; McKinley *et al*. 2017). Citizen science aims to have benefits beyond research and monitoring outcomes; it can foster greater value in natural heritage via community education, skills development, strengthening of community networks, and changing attitudes and behaviours (Brossard *et al*. 2005; Bonney *et al*. 2009; Jordan *et al*. 2012; Toomey and Domroese 2013; Lewandowski and Oberhauser 2017; Roetman *et al*. 2018).

Interest in a specific topic can be a key motivating factor for community members that participate in a project (Domroese and Johnson 2017). An interest in the bats of the South Australian MDB region was observed before the present study. First, there was sustained popularity of 'bat information nights' held across the region during 2006–2017. Second, a small-scale, successful project engaging citizens in bat surveys was initiated by the government agency NR SAMDB in mid-2015, itself emerging from a previous smaller community-based bat monitoring project run by Mid Murray Landcare South Australia and others. The combination of the need for data, a vast 70 000 km^2 area to cover, and demonstrable local interest in bats made the South Australian MDB region highly suitable for a citizen science project focussed on insectivorous bats (hereafter 'microbats').

The subsequent 'MEGA Murray–Darling Basin Microbat Project' (hereafter the MEGA Microbat project) was established with four aims: (1) collect new records of occurrence for microbat species across the South Australian MDB region to inform species conservation status reassessments and guide decisions on conservation; (2) identify habitat associations across the South Australian MDB for supporting the greatest species richness of bats; (3) contribute to the general understanding and appreciation of microbats by engaging the community in data collection and conservation initiatives on their own land; and (4) promote the program to other regions within the MDB and elsewhere to extend knowledge of bat distributions and community engagement with native fauna and science. It is an example of a semistructured project (*sensu* Welvaert and Caley 2016). Achieving these aims required the collaborative efforts of a management team from diverse institutions and professional backgrounds. It comprised expertise to conduct social evaluations, engage communities, and develop a regionally focussed and expedient semiautomated bat echolocation call identification system. It also required a connected network of Landcare associations to assist with the distribution of project materials.

Methods

Acoustic data collection

The study site comprised the entire South Australian portion of the MDB, which covers an area of ~70 000 km^2. The core activity was the collection of sound recordings with bat detectors, which contain a microphone sensitive to ultrasonic bat calls. The detectors make full night recordings and save sound files to a flash memory card. Most bat species in the region can be identified from their echolocation call characteristics, although typically within any assemblage a proportion of bat species produce calls that are very similar and difficult to distinguish (e.g. Pennay *et al*. 2004). The collection and analysis of bat calls is an expedient way to survey bats and, for most species, has a higher encounter rate than trapping (e.g. Duffy *et al*. 2000; Hourigan *et al*. 2008). Therefore, using bat detectors was considered to be an ethical, efficient and safe way to involve the general community directly in data collection processes.

A total of 30 Titley Scientific Anabat Swift bat detectors was available for distribution. Each unit was labelled with a unique, memorable name (a female name beginning with the letter M that participants could readily refer to), plus the factory-provided serial number of six digits, which allowed tracking of units and data across participants. The Anabat Swift was selected because it is simple to use, has a programmable recording schedule, collects a GPS (Global Positioning System) coordinate automatically at the start of a recording (allowing independent verification of recording site location), and makes triggered recordings in high quality WAV format at a maximum sample rate of 500 kHz. The full spectrum recording format will be forwards-compatible with future efforts and retrospective reanalysis, especially if new approaches are developed for separating species with similar calls.

Bat detectors were distributed via seven local Landcare network offices and three Natural Resource Offices spread across the South Australian MDB region. This localised coordination minimised travel time for participants collecting and returning equipment and allowed them to interact with the project through a familiar local organisation. Community participants were initially engaged in the project at ‘bat nights’ (an initiative of the Australasian Bat Society, Inc.) held across the region through Landcare organisations, as well as through local networks and radio and print stories in regional and state media outlets.

When bat detectors were borrowed by participating citizen scientists, they received verbal and concisely written instructions via their local Landcare officer on how to use the device, as well as how to collect and submit habitat data. Detectors were deployed by participants for at least one night in an area of their choice, with automated recordings made between sunset and sunrise. A recording site was one bat detector position/location on one night. Additional sites on subsequent nights were defined as GPS points at least 50 m away. Survey sites were typically located on the private land of the participants, but other survey sites included reserves. Detectors were also placed opportunistically on houseboats and commercial paddleboats as they travelled the lower Murray River. Surveys occurred over two seasons during warm months (October 2017 to May 2018; October 2018 to May 2019).

Collecting covariate data on site characteristics

A custom BioCollect data portal on the Atlas of Living Australia (ALA), accessible from a smartphone app or website, allowed participants to input site information while in the field. Project officers could also input site data to the website from paper datasheets submitted by participants. A site photograph, taken in the same direction that the microphone was pointing, was uploaded to the portal, which allowed independent verification of site characteristics. Habitat characteristics were collected to help explain the diversity and composition of bats. Four categorical habitat covariates were recorded by participants at the time of the acoustic survey: (1) flight space (FS), as a categorisation of the general structural habitat in front of the microphone; (2) nearest open water source (NOWS); (3) vegetation type (‘veg’); and (4) orientation of the microphone (‘mic’) (Table 1). Major vegetation community types of the South Australian MDB differ north and south of the Murray River (grouping options in Table 1 for ‘veg’ were derived from the National Vegetation Information System V5.1: Australian Government 2018).

Processing field recordings, call identification and verification

Bat species were identified by comparing the signal characteristics of echolocation calls in field recordings with those of reference calls collected from South Australia (D. Matthews, unpublished recordings from Gluepot Reserve in South Australia; and our own recordings made from captures at Chowilla) and Victoria (echolocation call files from L. Lumsden, Authur Rylah Institute for Environmental Research, Victoria). The identity of bats captured for reference call collection in South Australia was made using information on external morphology, including penile characters, in Churchill (2008) and Van Dyck *et al*. (2013). The total field recording dataset collected over two years was ~2 terabytes in size, and was archived on external drives, with recordings trackable via bat detector label and survey night.

Analysis of the field recordings produced a bat species list for each nightly bat detector site. Manual inspection of sound files is not expedient for datasets of this size (e.g. Andreassen *et al*. 2014), so non-specialist volunteers with some previous experience in bat call analysis were trained in a customised semi-automated process adapted from one used to process large full spectrum recording datasets of insectivorous bats from Indochina through to New Guinea and northern Australia, and Africa (Armstrong *et al*. 2015*a*, 2015*b*; Armstrong 2017; Katunzi *et al*. 2021). This process includes automated feature extraction, classification of unknown cases in a Discriminant Function Analysis (DFA), and manual verification of each identification per recording site based on inspection of a relatively small sample of spectrograms. Prior to the processing of the field recordings, the classifier step was built using the available reference echolocation call recordings. Metrics were derived from search phase echolocation pulses in Anabat Insight (Titley Scientific; various versions; full standard set of 19 metrics). Anabat Insight derives these metrics from signals that it recognises after converting full spectrum calls to Zero Crossings format (Zero Crossings threshold was set to 13). The metrics derived from all good quality, non-fragmented examples of single pulses in the reference call dataset were then compiled into a single text file, and the separation of species based on these echolocation metrics was tested using linear DFA on 17 of these variables (Fig. 1; Appendix 1). Data were available from

Table 1. Explanation of the acronyms used to describe ecological characters (categories of habitat covariates) chosen by citizen scientists in the BioCollect app

Number of sites for each factor level in statistical analyses is provided (factor mic was not analysed, but level totals are still reported)

Flight Space (‘FS’)		
The type of general habitat in front of the microphone that might be used for foraging by bats.		
DL	Over water body – lake, wide river, dam	78
G	House garden	124
IS	Windrow/shelter belt or isolated stand of trees	40
OP	Open pasture or parkland with no or sparsely scattered trees	56
R	Riparian vegetation around watercourse or lake	133
SC	Shrubland, vines or orchard (no overstorey above 2 m)	39
WL	Woodland and forest (overstorey above 2 m)	175
Nearest Open Water Source (‘NOWS’)		
Most bats in South Australia drink from open water sources, so descriptor categories were included for the nearest water source.		
D	Dam	54
L	Lake	8
MR	Murray River main channel	117
NWS	No significant water sources within 50 m	333
OSF	Other river/stream with flowing water	28
OSP	Other river/stream with intermittent pools	55
WT	Large open water tank accessible to bats	36
W	Wetland	14
Vegetation (‘veg’)		
Major vegetation community types.		
CD	Coastal dunes in Coorong region	10
ES	Estuarine habitat – Lower Lakes and Coorong	10
GZ	Grazing land with scattered gum trees – flanks of eastern hills	86
I	Irrigated horticulture and dairy farming along the River Murray	30
MN	Mallee north of River Murray	107
MS	Mallee south of River Murray	46
NG	Native grassland, chenopod shrublands	7
OW	Open woodlands with open understorey – low rainfall	45
RMC	River Murray corridor floodplains and wetlands	153
SEW	Artificially constructed and managed wetlands and sewerage ponds	1
TFD	Tall forests and woodlands with dense shrub understorey	3
TFO	Tall forests and woodlands with open shrub understorey	37
U	Urban areas	85
WCG	Wheat/cropping/grazing land interspersed with mallee – south and west of River Murray	25
Orientation of microphone (‘mic’**)**		
H2O	Over water	142
V	Into vegetation	390
WOS	Into wide open space	216

15 600 pulses in 637 echolocation sequences from 16 species (Appendix 2).

The acoustic processing pipeline used for the field recordings began by deriving the same 19 acoustic metrics in Anabat Insight in an automated operation using a generalised filter to find any signal that appeared to be a bat call (making ‘bulk measurements’ from ‘putative bat calls’). Three steps were then undertaken in a ‘shiny’ (Chang *et al*. 2019) implementation of an {R} language script. First, the measurements from reference calls were used again to calculate the maximum acoustic separation of species groups defined *a priori* using a linear DFA (the extraction step) with the ‘lda()’ function from the ‘MASS’ package (Venables and Ripley 2002). Second, in the assignment step of a DFA, the bulk measurements from Anabat Insight were then used to assign putative bat pulses to an ordination with 68% (approximately one standard deviation; first two Discriminant Functions) species data ellipses derived from the reference calls. This gave a preliminary identification of each pulse, being represented either in one of the data ellipses for the various species, or outside all ellipses. Bat calls were mostly separated from noise and other signals, but data ellipses for each species did contain points derived from these other sources and misclassified species. In the third step, each species identification from a particular survey site was checked to ensure that at least one point (representing a single pulse) in each of the data ellipses of the DFA plot were actually derived from a correct representative call of that species rather than another signal. The shiny app facilitated the opening of WAV files associated with points that were selected from the DFA plot. WAV files were opened from an import list made for Audacity ver. 2.3.0, and viewed in a spectrogram. To allow future verification, the Microsoft Windows Snipping Tool was used to capture a screenshot of one example for each species per night. Using this approach, one night of data could be analysed in a maximum of ~10–15 min compared with one hour using manual techniques, a projected saving of at least 200 h for this project.

The DFA provided a first pass at species identifications (Fig. 1). When one good example of a call classified correctly to a species data ellipse had been observed in the chosen WAV files, that species was designated as present for the site. Difficulties arose where species data ellipses overlapped. Where points were represented within the overlapping area of two or more species data ellipses, the identifiers needed to examine multiple WAV files to search for subtle features of pulses that allowed discrimination of the similar call types. As an example, the variation in calls of *Chalinolobus gouldii* overlaps with that of all three species of *Ozimops* present in the region. An unambiguous identification of *C. gouldii* was decided if a pattern of alternating high and low characteristic frequency was observed in the successive pulses in a call sequence attributable to a single individual. Species of *Ozimops* were distinguished from *C. gouldii* by the shallower initial frequency sweep and pulse shapes that were less consistently curvilinear (a less regular curve) and had small terminal droops. In the case of the three species *Vespadelus baverstocki*, *V. darlingtoni*, and *V. regulus*, there were no diagnostic features that allowed their separation, so they were combined. Verification of some of the more challenging species calls (for example, of *Myotis macropus*) was provided by Dennis Matthews, who has extensive experience with South Australian bat calls.

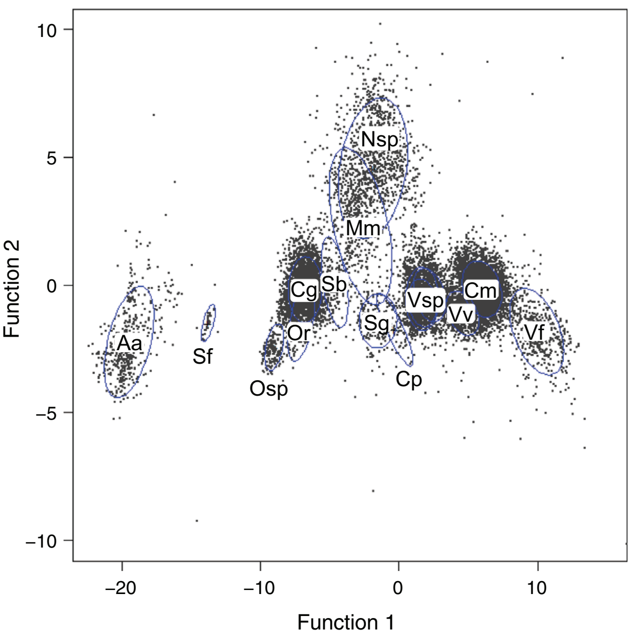

Fig. 1. Discriminant Function Analysis classification of reference calls collected from bats of verified identity in South Australia and Victoria (see Appendix 1 for coefficients of linear discriminants).

The resulting species list and screenshot spectrogram examples from each survey night was matched to field site data and uploaded to BioCollect. These data are freely available (https://biocollect.ala.org.au/acsa/project/index/f6c54c3a-5be3-4bf3-8f0d-f80d4d8070b4?tab = data-tab). The information will ultimately be stored in the Biological Database of South Australia, be publicly available through Nature Maps (http://spatialwebapps.environment.sa.gov.au/naturemaps/) and become part of the ALA records (www.ala.org.au). The compiled information is consistent with recommendations for presenting the results of acoustic surveys for bats (ABS 2006).

Analysis of occurrence records

The full dataset comprising species records and associated site information collected over the two seasons of the project (2017–2019) was downloaded from BioCollect on 24 June 2019. The dataset comprised 3042 species entries (796 deployment sites, 290 recording nights), which reduced to 3000 species records (754 deployment sites, 284 recording nights) following the removal of uninformative entries that resulted from problematic recordings (any entry without a species identification); and for statistical analyses to 2542 species records (645 deployment sites) after removal of entries with incomplete habitat descriptions. Other records of bat species distributed across South Australia were downloaded from the Atlas of Living Australia (Atlas of Living Australia 2019) on 29 June 2019 so that the contribution of the project could be compared with and visualised against the sum of past database contributions. These past records were not included in statistical analyses undertaken on project data. There were 2693 records of bat species from within the South Australian MDB NRM region, representing both preserved specimens in museums and direct observations without an associated specimen, with records extending from 1890 to 2018.

Plotting of the geographic distribution of recording sites and species occurrences from BioCollect and the ALA was undertaken in Quantum GIS ver. 3.4.9 software (QGIS). Summaries and statistical analyses of the BioCollect dataset were performed in a script in the {R} statistical computing language (R Core Team 2020). Species richness was also assessed against habitat covariates (FS, NOWS, veg; but not mic) available from the BioCollect entries (Table 1). The accuracy of 'veg' category classifications by citizen scientists was checked by mapping sites and observing the distribution of each category in comparison with the plotted major vegetation subgroups of the National Vegetation Information System V5.1 (Australian Government 2018). An extra habitat covariate, MNS, was also determined; it was derived from a query in QGIS, which categorised points as being within 2 km of the Murray River main channel, or north, or south of this linear region. We used a Bayesian multinomial logistic regression model implemented in the 'brms' package (Bürkner 2018) in {R} to assess the relationship between habitat covariates and species richness because species richness is a count variable. These statistical methods correspond to the multinomial character of the response variable, which here is species richness. Priors were chosen to be weakly regularising to control for both under- and overfitting of the model to the data. Convergence criteria, such as effective sample sizes and R-hat values, were used to check for appropriate model convergence throughout, and trace plots were inspected for signs of incomplete mixing when necessary. Model fit was assessed using the Watanabe–Akaike information criterion (WAIC) (Watanabe and Opper 2010). We accounted for spatial autocorrelation by reasoning that sites that were close to each other were more likely to be in the same habitat covariate and so were grouped similarly in the analysis.

The composition of the bat species assemblage was also compared among recording sites and habitat categories using the multivariate ordination method Non-metric Multi-Dimensional Scaling (NMDS) (based on the calculation of pairwise Bray–Curtis Dissimilarity among sites, with the presence/absence of each species listed for each site). The Indicator Species index (Dufrene and Legendre 1997; implemented in the {R} package 'labdsv': Roberts 2019) was calculated for covariates FS and veg using presence/absence data and is similar to relative abundance but highlights the association of each species with particular habitats. Species found in many habitat types tend to have relatively low scores, and those with a relatively high score for a particular habitat might have a specialist requirement for it. In this study, the measure allowed assessment of which species might be negatively or positively affected by modification of the original native vegetation, or that may have particular habitat preferences.

Evaluation of community participation and attitudes

A social evaluation instrument (Appendix 3), developed for the project, included online social surveys completed by citizen scientists at the beginning of their participation (e.g. at a bat night or before borrowing a bat detector), and towards the end of the project. The first social survey gauged participants' level of involvement, motives for becoming involved in the project, and knowledge of microbats and their habitats. Following the completion of analysis for each participant's recording, species lists were returned to individual participants through Landcare officers, along with an information brochure on how private lands could be modified to promote bat habitats. A newsletter updating participants on project progress was distributed periodically via email. In the post-involvement survey respondents were asked if participating in the project had led them to change their land management practices or consider changing these practices in the future. The social surveys were primarily conducted online using the *Survey Monkey* platform, but paper-based surveys were also available. A project website (megamicrobat.org.au) was established to direct members of the public to the database, social survey and project information.

Results

Species occurrence records

From 754 deployment sites, and 284 recording nights (meaning, on average, slightly less than three Swift units were out on any given night) collected over two seasons, 3000 bat species occurrence records were collected. When the GIS coordinates associated with each recording site were plotted, the extensive coverage of the survey was evident (Fig. 2). Almost half (1306) of the bat species occurrence records were derived from the relatively narrow corridor along the Murray River; a further 1513 records were recorded north and 181 south of this corridor. The relative level of site sampling effort south of the Murray River was clearly low.

A total of nine species was recorded by the efforts of the citizen scientists, plus another three call types that each probably represent more than one species (*Nyctophilus* sp.: the long-eared bats *Nyctophilus corbeni* and *N. geoffroyi*; *Vespadelus* sp.: the evening bats *Vespadelus baverstocki*, *V. darlingtoni* and *V. regulus*; and *Ozimops* sp.: the free-tailed bats *Ozimops petersi* and *O. planiceps*: Table 2). Species were lumped into call types if the data ellipses from the DFA overlapped significantly and no species-specific pulse characters were evident in the spectrograms of the original recordings. The distribution of each species and call type representing two or more species showed some evidence of habitat preference for some species, but not for others (Fig. 3). For example, *Chalinolobus picatus* was detected only in mallee habitat north of the Murray River; *Vespadelus vulturnus* occurred in the Murray River corridor or more mesic areas closer to the Adelaide Hills region, whereas the other (combined) members of *Vespadelus* were found in all habitats. Similarly, most records of *Ozimops ridei* were from the Murray River corridor and habitats nearer to Adelaide, whereas the *O. petersi*/*planiceps* call complex had a more widespread distribution.

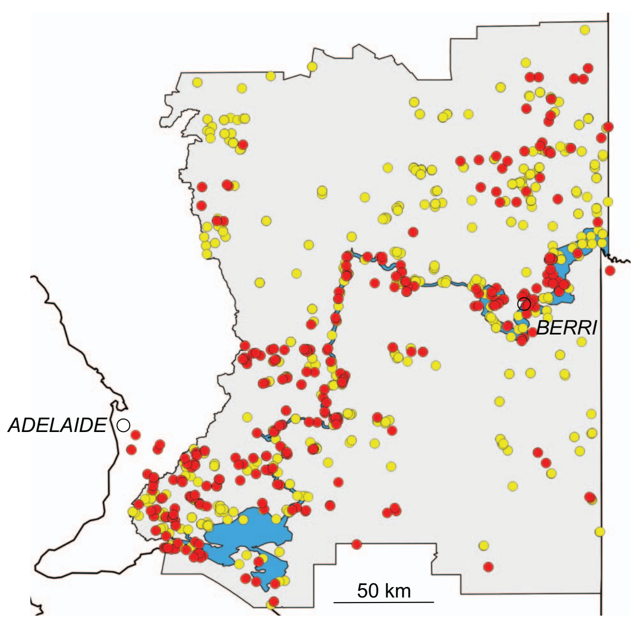

Fig. 2. All microbat species occurrence records from the MEGA Microbat study (red dots, which correspond to recording sites and contain records of one or more species; includes records in the ALA as yellow dots; grey shading represents the NRM regional boundary; blue polygon is the Murray River corridor).

Table 2. Occurrence records for each microbat species from presurvey and MEGA Microbat project survey

	ALA[A]	MEGA[B]
EMBALLONURIDAE (sheath-tailed bats)		
Saccolaimus flaviventris (yellow-bellied sheath-tailed bat)	5	0
VESPERTILIONIDAE (evening bats)		
Chalinolobus gouldii (Gould's wattled bat)	625	626
Chalinolobus morio (chocolate wattled bat)	242	198
Chalinolobus picatus (little pied bat)	26	12
Myotis macropus (large-footed myotis) (= fishing bat)	26	4
Nyctophilus corbeni (Corben's long-eared bat)	56	–[D]
Nyctophilus geoffroyi (lesser long-eared bat)	434	302
Scotorepens balstoni (inland broad-nosed bat)	38	1
Scotorepens greyii (little broad-nosed bat)	1	0
Vespadelus spp. (evening bats)	78	473
Vespadelus baverstocki (inland forest bat)	192	–[C]
Vespadelus darlingtoni (large forest bat)	53	–[C]
Vespadelus finlaysoni (Finlayson's cave bat)	1	1
Vespadelus regulus (southern forest bat)	88	–[C]
Vespadelus vulturnus (little forest bat)	105	316
MINIOPTERIDAE (bent-winged bats)		
Miniopterus orianae bassanii (southern bent-winged bat)[E]	1	0
MOLOSSIDAE (free-tailed bats)		
Austronomus australis (white-striped free-tailed bat)	114	485
Ozimops petersi (inland free-tailed bat)	64	–[F]
Ozimops planiceps (southern free-tailed bat)	417	523
Ozimops ridei (Ride's free-tailed bat)	30	59
Total records	2591[A]	3000
Total species richness	19	up to 16

[A]ALA – Atlas of Living Australia records 1890–2018, with 105 records attributed to genus only removed, as well as records for *Pteropus poliocephalus* and questionable records for *Macroderma gigas*, *Nyctophilus bifax*.
[B]MEGA – MEGA Microbat project BioCollect records 2018–2019.
[C]Grouped as *Vespadelus* spp.
[D]Calls indistinguishable from those of *N. geoffroyi*.
[E]*Miniopterus orianae bassanii* is present on the ALA database as *M. schreibersii*.
[F]Indistinguishable from calls of *Ozimops planiceps*.

Some species appear to be relatively restricted in their distribution: calls that could be attributable to *Vespadelus darlingtoni* were observed at three locations only: Keyneton/Sedan, Mannum and Nangkita (map not shown); there was a single occurrence of *Vespadelus finlaysoni* near Burra; and *Scotorepens balstoni* was identified from a single location north of the Murray River. The known range of *Myotis macropus*, listed as Threatened under the *NPW Act 1972* was extended by four new records of bats foraging over the main channel of the Murray River. These records were collected via opportunistic surveys from a houseboat travelling up and down the river. Other putative identifications of this species were made elsewhere (Adelaide Hills, Goolwa), where confusion with the call type of a species of long-eared bat (*Nyctophilus*) could not be ruled out. Only three species of microbat known from the region were not detected unambiguously on the survey: the yellow-bellied sheath-tailed bat (*Saccolaimus flaviventris*), the little broad-nosed bat (*Scotorepens greyii*), and the southern bent-winged bat (*Miniopterus orianae bassanii*), all of which were rare occurrences in the past.

An alternative identification for the single occurrence we recorded of *V. finlaysoni* is the high frequency phonic type of *V. regulus*. Law *et al*. (2002) documented geographic variation in the characteristic frequency of echolocation calls of several species of *Vespadelus* in New South Wales, including a high frequency phonic type (54–55 kHz) of *V. regulus* in the Riverina region. The distribution of this phonic type might extend westwards into South Australia along the Murray River and adjacent habitats and could account for our record of '*V. finlaysoni*' near Burra and the older record south of Meningie (designated as a 'human observation' in the Atlas of Living Australia 2019) (Fig. 3). The possibility of species-level cryptic diversity would need to be explored so that issues around identifying the calls of *V. regulus* can be resolved, and we have retained the name *V. finlaysoni* in the interim. Blakey *et al*. (2017) found that *V. regulus* was the most active species on the Chowilla floodplain, but this species was not amongst our 67 captures when we visited Chowilla to collect reference calls.

Species richness and habitat

Our Bayesian multinomial logistic regression models showed that each general category of habitat covariates resulted in similar patterns of the probability of species richness. Probability of species richness amongst the FS levels was

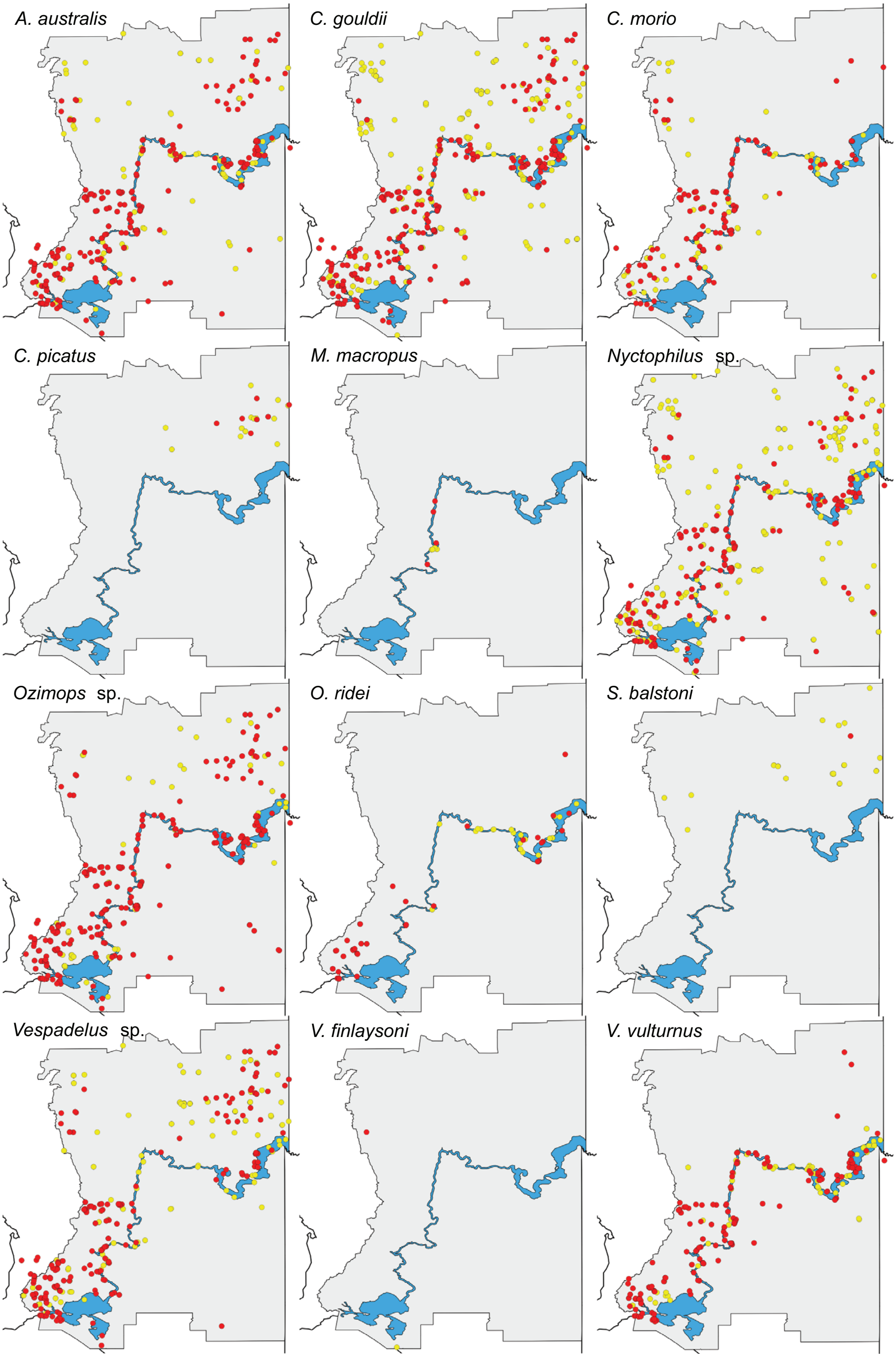

Fig. 3. Summary of occurrence records for most bat species detected on the MEGA Microbat project (note that some species have been combined based on a single 'call type'; yellow dots are ALA historical records, red dots are records from MEGA Microbat project).

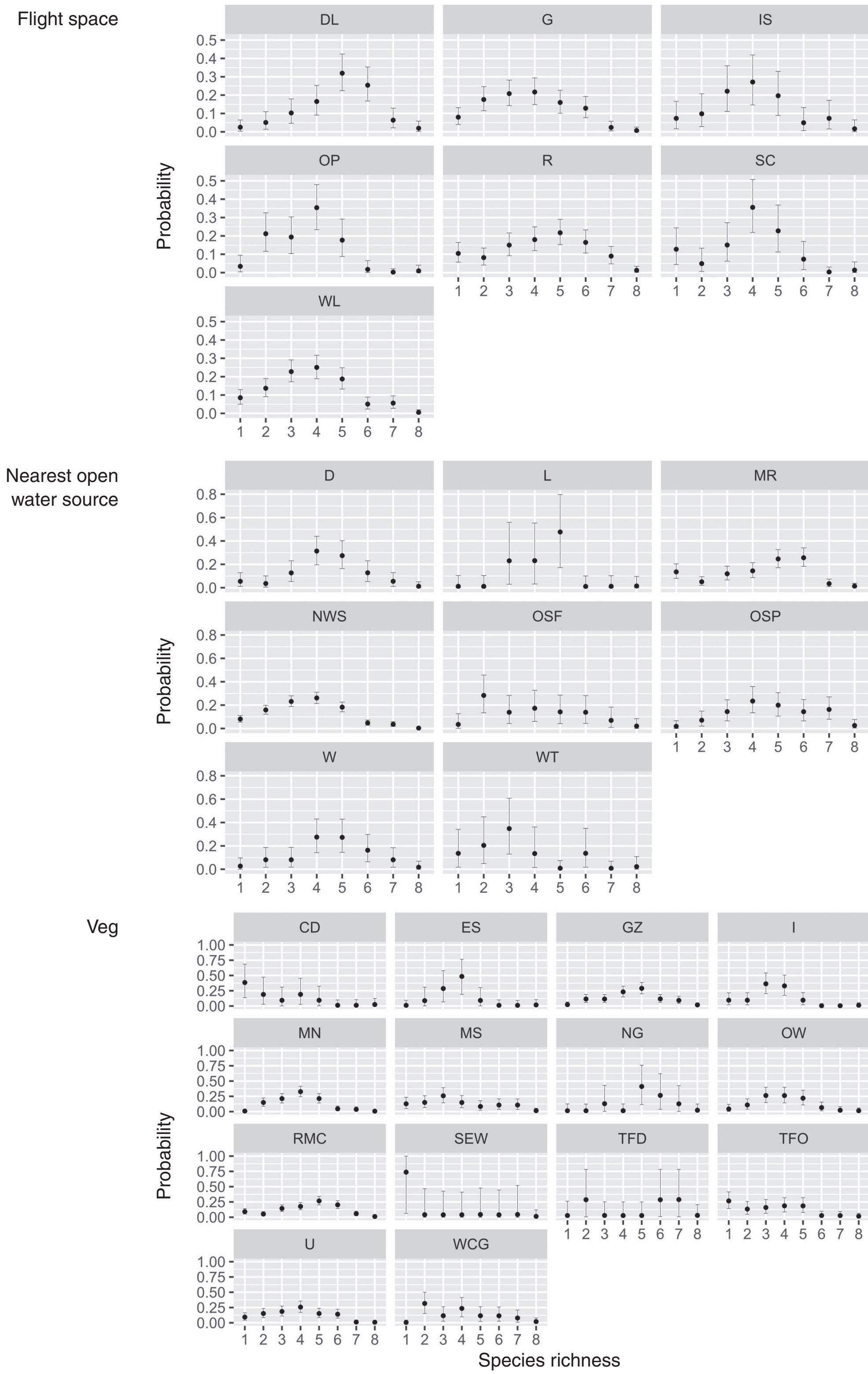

Fig. 4. Probability of the level of species richness in each category of a habitat covariate type (see Table 1 for explanation of category acronyms).

similar, with the highest species richness probabilities occurring at four or five species in each category (Fig. 4). The distribution of probabilities for species richness was approximately Gaussian in shape with lower probabilities occurring at one and eight species. For any given site, the greatest probabilities for high levels of species richness (six species) occurred in the categories that included water sources (DL, R; over water bodies, and riparian vegetation; Table 1), but there was no significant difference in the patterns between them and the remaining categories.

Given that most bats in South Australia drink from free-water sources, and insect biomass is greater in wetter areas (Blakey *et al*. 2017), particular focus was given to identifying the type of nearby water source and investigating the relationship between water source type and bat species richness. Patterns of the probabilities of species richness among water source types was generally similar (NOWS: Fig. 4). The highest probabilities of species richness among categories were between three and six species, with the greatest probability at five species for lakes (L), and generally relatively high probabilities for low species richness values for sites with no significant water source within 50 m (NWS). The highest probability for the Murray River main channel (MR) category was at six species, and no other site had as high a probability for this level of species richness. The NOWS model had the lowest WAIC value and highest Akaike weight, indicating that this habitat covariate will make the best predictions on new data (Table 3).

Most vegetation types appeared to be relatively similar in terms of species richness (veg: Fig. 4). Some patterns are most likely the result of relatively low sampling effort, with a case in point being the probabilities skewed towards low species richness for artificially constructed and managed wetlands and sewage ponds (SEW). Tall forests and woodlands with a dense shrub understorey (TFD) recorded the highest probabilities for the greatest bat richness, with most of these sites recording six species, and some seven species. The Murray River corridor (RMC), which contains both riparian vegetation and flight spaces over water, also had relatively high species richness, with the highest probabilities for five and six species.

Species composition

Grouping of recording sites based on the similarity of the bat species present was analysed with NMDS. The model converged after 20 iterations, but there was no strong pattern in bat species composition according to any habitat category. No clear difference is evident in the composition of bats from sites with or without an identifiable water source within 50 m (Table 1; Fig. 5*a*). The only observable trend was a small difference in the bat species composition of sites in the Murray River corridor and the combined habitat areas north of the river (categories for MNS: Fig. 5*b*).

Table 3. Model comparison using WAIC

Lower values indicate preferable models. The weight of a model is its Akaike weight, interpretable as the probability that a candidate model will make superior predictions on new data

Model	WAIC (s.e.)	ΔWAIC (s.e.)	Effective parameters	Weight
Nearest Open Water Source	2379.1 (32.1)		50.6	1
Flight Space	2396.9 (30.3)	17.8 (23.2)	45.4	0
Vegetation	2397.8 (35.1)	18.8 (31.9)	79.6	0

Indicator Species

The Indicator Species indices show a pattern that suggests most bat species did not have a strong preference for or against certain habitats, modified or otherwise. There were few species that had relatively high values of the index for a given category in the covariates FS and veg (Fig. 5*c, d*). However, it was clear that *C. morio*, *M. macropus*, and *V. vulturnus* had an obvious preference for foraging over large water sources (DL) and riparian habitats (R) compared with drier habitats. Other species of *Vespadelus* and *C. picatus* had a clear preference for woodland habitats (WL). When the index was recalculated for each species using veg categories, the same association of *C. morio*, *M. macropus*, and *V. vulturnus* with large water sources and riparian habitats was evident (RMC). In addition, an interesting observation was the relatively strong association of open space foragers *A. australis* and *O. ridei* with tall forests and woodlands with a dense (rather than open) shrub understorey (TFD). The strong association of *C. picatus* with mallee north of the Murray River (MN) is obvious from mapping (Fig. 3) and supported by our captures in this habitat.

Social survey results

The preinvolvement survey was completed by 214 respondents. In the survey, participants were asked why they wanted to become involved in the project. The responses to which most participants agreed were: *Native wildlife is important to me* (92%), *Conservation is important to me* (92%), *I think this project will be interesting* (86%) and *I want to learn about microbats* (86%).

The post-involvement social survey was completed by 54 participants. Twenty-one respondents (39%) indicated that they had changed how they managed their property since participating in the project. Eighteen of those respondents (33%) described the changes in open-ended responses, including: planting vegetation (7 respondents), protecting trees (7 respondents), installing nest boxes (6 respondents), ceasing or reducing the use of pesticides or herbicides (2 respondents), and managing water sources (2 respondents). Additionally, 38 respondents (70%) indicated that they were likely to do things differently on their property to support wildlife in the future. Specific activities that respondents indicated they were likely to implement were: promote retention of tree hollows, bark crevices, or install wildlife boxes (46 respondents); protect scattered native trees and dead trees (43 respondents); protect a block of remnant vegetation (42 respondents); use land management practices for healthy trees (41 respondents); plant revegetation areas (36 respondents); reduce the use of pesticides or herbicides (35 respondents); and manage watercourses or dams (30 respondents).

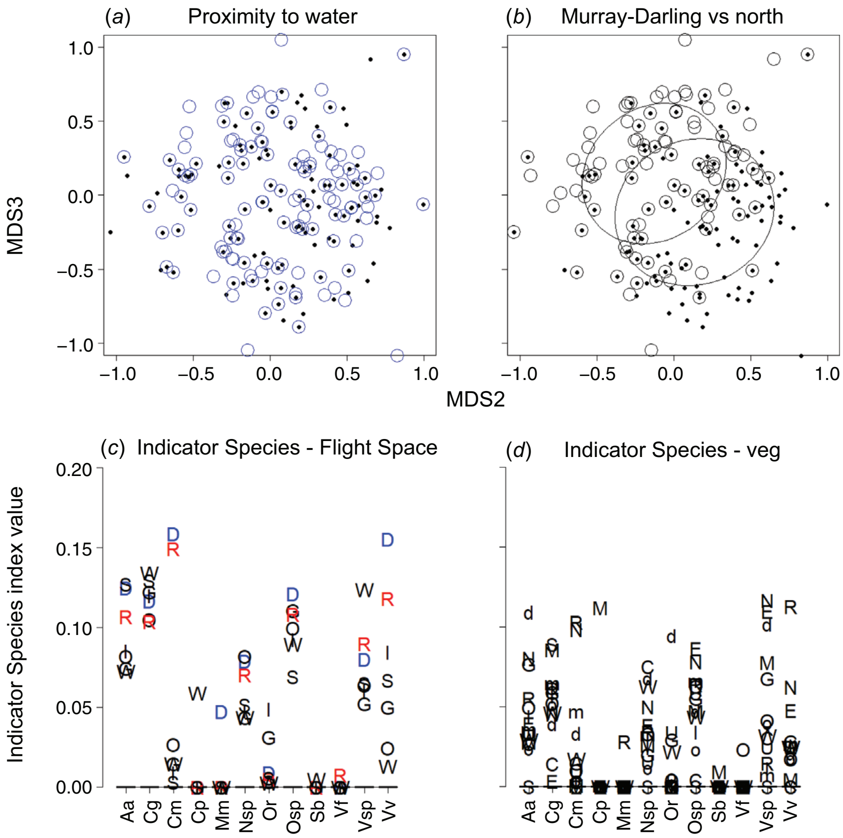

Fig. 5. Various summaries of species composition and species richness. (*a*) Non-Metric Multidimensional Scaling (NMDS) multivariate analysis to illustrate patterns of species composition among recording sites with any kind of nearby water source (blue circles), and away from sources of water (black dots); (*b*) the same NMDS plot but with site symbols for their location within the Murray River corridor (black circle) or north of the Murray River (black dot; sites for south of the Murray River not included); (*c*) Indicator Species values for Flight Space categories in each species (see Table 1, plotted symbols are the first letter of each category; coloured symbols are those of particular interest given their association with water); (*d*) Indicator Species values for veg categories in each species (see Table 1 for plot symbols; abbreviations here are: C for CD, E for ES, G for GZ, I for I, M for MN, m for MS, N for NG, O for OW, R for RMC, S for SEW, d for TFD, o for TFO, U for U, W for WCG). Species are: Aa, *Austronomus australis*; Cg, *Chalinolobus gouldii*; Cm, *Chalinolobus morio*; Cp, *Chalinolobus picatus*; Mm, *Myotis macropus*; Nsp, *Nyctophilus corbeni*/*Nyctophilus geoffroyi*; Osp, *Ozimops petersi*/*Ozimops planiceps*; Or, *Ozimops ridei*; Sb, *Scotorepens balstoni*; Vf, *Vespadelus finlaysoni*; Vsp, *Vespadelus baverstocki*/*Vespadelus darlingtoni*/*Vespadelus regulus*; Vv, *Vespadelus vulturnus*.

Discussion

Overall contribution to the public database

The collaboration of scientists with local landholders and the Landcare network has more than doubled the number of bat species occurrence records for the South Australian MDB in two years (3000 records; cf. 2693 records between 1890 and 2018). While conspicuous geographic sampling gaps remain, particularly south of the Murray River (Fig. 2), being able to provide specialist but simple-to-use recording equipment to interested and motivated members of the general public was clearly successful for providing an updated perspective of bat occurrence across the region. In addition, the two primary scientific outputs — the data in the BioCollect portal, and the summary report distributed to the South Australian DEW, the MDB Authority, Victorian Department of Environment, Land, Water and Planning, and New South Wales Primary Industries (Armstrong *et al*. 2019) — has meant that the data are available to Government land managers across the MDB, as well as to non-government organisations that manage natural ecosystems. Although the study received funding from the Commonwealth Government, the resources (the equivalent of ~1.5 full-time-equivalent salaries) could not have been extended without the assistance of the citizen scientists and volunteers. Thus, in terms of the amount of data collected and analysed in a relatively short timeframe, the involvement of citizen scientists in producing a significant volume of data was tremendously productive.

Data quality

When examining the quality of the data, it was apparent that the involvement of citizen scientists also provided useful information relevant for bat species management in the MDB; for example, the unambiguous detection of species that are relatively rare or restricted to certain habitats within the region (*C. picatus*, *S. balstoni*, *V. finlaysoni*). The geographic extent of detections and encounter rate of *C. picatus* (Endangered under the *NPW Act 1972*) (Fig. 3) is a good example of having contemporary records available to inform forthcoming state conservation status reassessments. The novel idea of attaching a bat detector to boats travelling along the river also extended the known foraging range of one relatively rare species (*M. macropus*; listed as Endangered under the *NPW Act 1972*). That observation provides the basis for suggesting the presence of roosts not yet discovered, and which will also inform conservation status reassessments.

For rarer bat species, with echolocation calls similar to those of more common species, there will likely always be challenges for their unambiguous confirmation of occurrence if surveys rely solely on acoustic methods. For example, *V. darlingtoni* is present around the Adelaide Hills, but detecting it across wider areas was hindered by the presence of other *Vespadelus* species with similar calls. The quality of occurrence data is therefore derived mainly from how well the analysis system can separate species with similar call types. Distinguishing the source of two very similar echolocation types is an enduring challenge in bat biology, and is a feature of most bat assemblages worldwide (e.g. Russo *et al*. 2018). This difficulty persists regardless of whether the analyst is a trained volunteer, or an 'expert' bat biologist experienced with identifying bat echolocation calls. In the present study, we used a semi-automated approach for processing recordings and identifying calls, involving verification of subsets of results (per site) from multivariate analysis by trained volunteers, and follow-up validation by experts for particularly challenging cases. This approach differs from that taken by the FrogID citizen science project (Rowley *et al*. 2019; Rowley and Callaghan 2020), which used primarily expert validation. However, bat calls are relatively discrete compared with those of frogs, and they occur in the ultrasonic part of the spectrum where there is less background noise. It is therefore straightforward to separate bat calls in automated processes that track the frequency trends of single pulses in the time–frequency domain. Given the rapid developments in the field of machine learning, there is potential to improve rates of successful classification in the future, thus reducing the reliance on trained volunteers and experts alike. Having a great amount of information on the extent of variation in the calls of each species will help train automated processes. Yet, confounding degrees of overlap among species may persist because echolocation signals have primarily a sensory function rather than an advertisement call for species discrimination, mate attraction and sexual selection as in frogs.

An additional consideration for data quality is the reliance on where citizen scientists choose to place their bat detector and microphone. Placement was directed to some degree by the project coordinators, but broad areas of the MDB region in South Australia remained unsampled. Haphazard sampling can limit the power of citizen science-based efforts to collect large datasets across wide areas (Callaghan *et al*. 2019). The corollary of this bias is that greater attention is given to areas that have higher levels of anthropogenic land use, such as the Murray River corridor where the bat assemblage might be subject to a wider range of threats, in contrast to areas of mallee woodland. In addition to site selection, microphone placement may have affected the likelihood of detecting bats. Microphones placed in thick vegetation probably had reduced detection volumes compared with those facing open spaces because of acoustic reflections away from the microphone. However, it is well established that different bat species prefer open, edge or closed habitats (Bullen and McKenzie 2001; Denzinger and Schnitzler 2013) so all habitat types need to be represented in large surveys.

Having basic occurrence information will be especially useful for environmental impact studies in these areas. Data collected in the present study are already finding relevance and application. For example, recent installation of large numbers of frost fans in horticultural areas was informed by this work. Discussion and empirical testing of the effects of windfarms on bats and birds is extensive in the scientific literature (Peste *et al*. 2015; Thaxter *et al*. 2017), but frost fans have received little attention. In addition to the data resource, the availability of recording equipment (30 professional-grade autonomous recorders) has stimulated interest in bat faunal assessments in other parts of the state. Furthermore, the Mallee Catchment Management Authority in Victoria successfully used our citizen science model to undertake microbat surveys in their region over the summer of 2019–2020. Since the MEGA Microbat project finished, the legacy bat detectors have been used by local government biodiversity staff from urban areas around Adelaide, on conservation lands managed privately by Bush Heritage Australia, biological researchers at the University of South Australia surveying Kangaroo Island, and others wishing to continue the effort in the MDB. They are also being used to investigate foraging habitats of endangered microbats in Fiji. Thus, the major output of the present study is not limited to a simple doubling in the number of databased records and the beginnings of conservation-based actions for bats on private land, but it has stimulated a greater capacity for incorporating bats into surveys across broad geographical areas, and internationally.

Encouraging bat diversity

The MEGA Microbat study presented evidence of a species-rich assemblage of bats that still exists throughout the MDB in South Australia. Areas that no longer support a diverse non-volant mammalian fauna can still contain numerous bat species. While it is perhaps unsurprising that the Murray River corridor supported up to eight species, as per previous studies (Lentini *et al*. 2012; Blakey *et al*. 2017), even urban gardens, cropping paddocks and grazing land, where human habitation had encroached on native habitats, were used by up to four species (Fig. 5 – veg). This richness was a source of surprise and encouragement to many participants. It also provided a solid basis for demonstrating that native mammal species persist in the landscape, and are therefore an important consideration for land management. The mere continued presence of native mammals helped emphasise the intrinsic value of wildlife.

Beyond the information sessions (e.g. bat nights promoted by the Australasian Bat Society, Inc.), media releases, and becoming involved in the project, returning the survey results to citizens provided another opportunity for education and promotion of conservation action on private land. Management advice included maintaining large trees, promoting understorey plants for native insects, maintaining water sources, and keeping pet cats inside at night. The value of native vegetation as bat habitat is also relevant to government land managers — extending the reach of citizen science to cover both private and government land holdings.

The habitats that appeared to provide more resources for bats were tall forests and woodlands with a dense shrub understorey (TFD), with sites most likely to have six or seven species; and the Murray River corridor (RMC) where sites were most likely to have five or six species (Fig. 4). These habitats offer roost sites in the large old trees and a variety of insects for food as well as different types of flight space, which supports a range of bat foraging strategies. Shrubby understorey also promotes insect biomass that represents bat prey. These habitats should be a priority for protection and management activities. Management activities in vegetation remnants need to accommodate their existing microbat communities, including their roost and food resources. Considerations to fire management approaches are relevant here since high fire frequency and intensity can remove the largest and oldest trees, which are most likely to provide roosting opportunity in hollows and under exfoliating bark. Management of vegetation remnants should maintain the diversity and cover of native understorey plant communities, which provide abundant insect prey resources for bats. Fencing remnant vegetation and wetland areas against intrusion by stock and targeted weed control activities will also benefit native plant understorey and the quality of freshwater resources.

Perception of the value of wildlife

The perception of the intrinsic value of wildlife is not only a necessary prerequisite for conservation, but it is axiomatic (Justus *et al*. 2009; Vucetich *et al*. 2015; Batavia and Nelson 2017). It is particularly relevant for animal groups, such as insectivorous bats, which have no obvious role in ecosystem services. Usually, fruit bats, the Pteropodidae, are cited as having keystone roles in pollination and seed dispersal for forest systems (Fujita and Tuttle 1991; McConkey and Drake 2006; Lobova *et al*. 2009), which are also linked to benefits for local communities (Scanlon *et al*. 2014). The primary utilitarian value of insectivorous bats in an anthropogenic context has been recognised as insect pest suppression in agricultural regions (Cleveland *et al*. 2006), or in an ecological context for suppression of insects in forest systems (Kalka *et al*. 2008; Williams-Guillén *et al*. 2008). Public perception of bats can be diverse, ranging from negative, ambiguous, to positive attitudes. For rural communities, conservation efforts will require an approach that can address any problematic perceptions of bats. This requires building social capital and relationships through involvement, allowing rural people to improve their understanding and appreciation of biodiversity, which can lead to positive biodiversity outcomes over large areas (Pretty and Smith 2004). The MEGA Microbat project focussed on regional areas outside the city of Adelaide. The social surveys showed that participation in the project prompted at least 70% of respondents to consider adopting the recommended management actions on their private land to enhance habitat for bats. We demonstrated that citizen science was an efficient way to conduct a broad-scale bat survey while building social capital, which itself built on earlier efforts in previous years at smaller scales.

Conclusion

The MEGA Microbat citizen science project achieved its aims, and developed the architecture to underpin future studies and efforts. A dearth of information on microbat species is not unique to the MDB region of South Australia, nor is an embedded interest from the community in bats and scientific endeavours. It is highly likely that results similar to that achieved by this project could be mirrored in interstate areas of the MDB, and elsewhere. For future projects to be successful, we recommend: engagement with a wide cross-section of the community; easy-to-use, reliable technology; a publicly accessible database; a rapid species identification technique; and timely reporting to the community, land and threatened species managers and policy makers. Many people have a latent interest in bats and nature and relish the opportunity to be involved in projects with demonstrable contributions to land management policy and biodiversity conservation.

Data availability statement

The records of bat occurrence are available publicly in several repositories. The raw data, which is the combination of the original submission by citizen scientists and the species identifications provided from the call analysis at these sites, are retained in the MEGA Murray–Darling Microbat Project BioCollect database: https://biocollect.ala.org.au/acsa/project/index/f6c54c3a-5be3-4bf3-8f0d-f80d4d8070b4.

A version that has been checked and curated has been submitted to the Biological Database of South Australia. This is accessible via NatureMaps and has been incorporated into the Atlas of Living Australia: https://data.environment.sa.gov.au/NatureMaps/Pages/default.aspx; https://www.ala.org.au/.

See also Atlas of Living Australia (2019), https://doi.org/10.26197/5d170396dd081.

Conflicts of interest

The authors declare no conflicts of interest.

Declaration of funding

Funding was provided from an Australian Government Inspiring Australia Citizen Science grant CSG56360, with in-kind support from the South Australian Museum, Natural Resources South Australian Murray–Darling Basin,

Department for Environment and Water, and the University of South Australia (UniSA).

Acknowledgements

We are grateful for the contributions of the many willing citizen scientists of the SA Murray–Darling Basin. The Landcare Officers from Berri Barmera Landcare, Coorong Tatiara LAP, Eastern Hills and Murray Plains Catchment Group, Murray Mallee LAP, Renmark Paringa LAP, and Riverland West Landcare undertook a large part of the community engagement. Martin Philcox assisted with bat call analysis and Dennis Matthews undertook verification checks of the more difficult-to-differentiate calls. Terry Reardon, Chris Grant, and Matthew Humphrey kindly assisted with various aspects of the project including microbat reference call collection. Hayley Tindle at UniSA reviewed the social surveys and assisted with project administration. The study had UniSA Human Ethics approval (200447), South Australian Wildlife Ethics Committee approval (34/2017), and a scientific permit from the South Australian Department of Environment, Water and natural Resources (Y26704-1) for the collection of bat echolocation reference calls.

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Handling Editor: Brad Law

Appendix 1. Coefficients of linear discriminants from the Discriminant Function Analysis

Only the first three linear discriminants (LDs) are given. Proportion of trace: LD1: 0.887; LD2: 0.058; LD3: 0.027. Description of variables is given in the Anabat Insight software manual (Titley Scientific 2020)

Variable	LD1	LD2	LD3
Dur.ms	–0.2310692	–0.0049002	0.7599587
Fend.kHz	0.0228093	–0.0400571	–0.0188293
Fmax.kHz	–0.0559342	0.0205468	0.0719951
Fmin.kHz	0.0932074	–0.1000628	–0.1323390
Fk.kHz	0.1664704	0.2941240	–0.0391491
Tk.ms	0.1463400	0.7941863	0.2256886
Fc.kHz	0.4653452	–0.1863953	0.1541593
Tc.ms	0.2081987	–0.1739454	–0.0874036
Sc.OPS	–0.0096156	0.0244980	0.0304698
S1.OPS	–0.0000125	–0.0002099	–0.0003231
PMC	0.0382532	–0.0118662	–0.0238091
Curvature	10.0641600	1.9303780	21.0025400
Smin.OPS	–0.0000359	0.0000171	–0.0000319
Smax.OPS	0.0000227	–0.0002802	0.0002163
Send.OPS	0.0002502	–0.0003075	0.0001762
psl	–0.0000006	–0.0000009	–0.0000017
pcmin	0.0079017	–0.0065186	–0.0104749

Appendix 2. Number of bat species, echolocation sequences and pulses in the reference call dataset

Species	Sequences	Pulses
Austronomus australis	19	506
Chalinolobus gouldii	88	2813
Chalinolobus morio	189	3666
Chalinolobus picatus	1	10
Myotis macropus	31	208
Miniopterus orianae bassanii	61	2956
Nyctophilus corbeni	5	14
Nyctophilus geoffroyi	97	1345
Ozimops planiceps	6	201
Ozimops ridei	2	57
Scotorepens balstoni	3	67
Saccolaimus flaviventris	5	26
Vespadelus darlingtoni	60	2087
Vespadelus finlaysoni	30	505
Vespadelus regulus	19	490
Vespadelus vulturnus	21	649
16 species	637	15 600

Appendix 3. Aims and questions included in the pre- and post-involvement survey of project participants

Preinvolvement survey aims

- Document the level of involvement in the project (e.g. short- or long-term)
- Understand the motives for participating in the project
- Gauge level of knowledge within the community about microbats and their habitat requirements

Preinvolvement survey questions (summarised; categorical answer selection)

General

- My general opinion of microbats is:
- If microbats were near your house today, please indicate how you would feel about them by responding to the following statements (10 statements)

Knowledge of microbats

- Microbats comprise approximately __% of native mammals in South Australia
- The diet of South Australian microbats includes:
- Key threats to microbats include:
- When do microbats sleep?
- Microbats sleep in:
- A baby microbat is called:
- Microbats navigate through the landscape using:
- We can help protect microbats by:

Your property

- How would you describe this property:
- How large is the property?
- How long have owned or been involved with this property?
- I would categorise this property as:

Management of property

- Series of questions about water, vegetation, native trees, tree hollows, pesticide and herbicide use on the property
- Please list up to three things that you do to support wildlife on the property:
- Please list three barriers to supporting wildlife on the property:

Involvement in project

- I want to be involved in the Murray–Darling MEGA Microbat Project because. . . (response to series of statements)

Participant details

Post-involvement survey aims

- Assess the influence of the MEGA Microbat Project on landholder behaviour
- Evaluate participant satisfaction levels to allow for continuous improvement in administering the MEGA Microbat Project

Post-involvement survey questions (summarised; categorical answer selection)

Motivation and involvement

- How were you involved in the Mega Microbat Project? (select category)
- I became involved in the South Australian Murray–Darling MEGA Microbat Project because. . . (indicate level of agreement with a series of statements)

Opinion of bats

- After participating in the MEGA Microbat Project, my general opinion of microbats is:
- If microbats were near your house today, please indicate how you would feel about them by responding to the following statements:

Bat knowledge

- Please select your response to the following statements: (preinvolvement bat knowledge questions reworded)

Influence on behaviour

- Since participating in the MEGA Microbat Project, how likely are you to do things differently on your property to support wildlife?
- Since participating in the MEGA Microbat Project, please indicate how likely you are to change your activities around the following attributes of this property:
- Since participating in the MEGA Microbat Project, how have you changed how you look after or manage your property? (open-ended question)
- Is there anything preventing you from making changes to your property? (open-ended question)