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RESEARCH NOTE

Can an acoustic observatory contribute to the conservation of threatened species?

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Abstract

Observatories are designed to collect data for a range of uses. The Australian Acoustic Observatory (A2O) was established to collect environmental sound, including audible species calls, from 344 recorders at 86 sites around Australia. We examine the potential of the A2O to monitor near threatened, threatened, endangered and critically endangered species, based on their vocal behaviour, geographic distributions in relation to the sites of the A2O and on some knowledge of habitat use. Using IUCN and EPBC lists of threatened and endangered species, we extracted species that vocalized in the audible range, and using conservative estimates of their geographic ranges, determined whether there was a possibility of hearing them at these sites. We found that it may be possible to detect up to 171 threatened species at sites established for the A2O, and that individual sites have the potential to detect up to 40 threatened species. All 86 sites occurred in locations where threatened species could possibly be detected, and the list of detectable species included birds, amphibians, and mammals. We have incidentally detected one mammal and four bird species in the data during other work. Threatening processes to which potentially detectable species were exposed included all but two IUCN threat categories. We concluded that with applications of technology to search the audio data from the A2O, it could serve as an important tool for monitoring threatened species.

KEYWORDS
amphibians, Australian acoustic observatory, birds, conservation, ecoacoustics, mammals, threatened species, vertebrates, vocalizations

INTRODUCTION

An observatory is typically a network of monitored sites. Observatories make observations of astronomical, meteorological or other natural phenomena for use in scientific study. Various observatories worldwide observe physical processes via sensors, such as light, x-rays and radio-waves entering the atmosphere from space, seafloor volcanism, hydrothermal vent systems, earthquakes, seafloor spreading, and subduction zones, temperature and salinity of the ocean, CO_2 flux, temperature and humidity. While mostly focused on physical processes, some observatories observe biological processes as well, such as the ENETWILD project, which collects wildlife movement and population size data at a European level to analyse risks of diseases shared between wildlife, livestock and humans (ENETWILD Consortium et al., 2021).

Acoustic observatories use arrays of recorders to record environmental sound, including natural physical sounds (geophony), animals (biophony) and man-made noises (anthophony; Pijanowski et al., 2011). Recording environmental sound allows detection of vocal or noisy species in the region, in addition to seasonal geophony, and anthrophony, allowing them to be examined in tandem. In addition, analysis of environmental sound can be used to focus on single species or groups, to study aspects of biology such as dispersal and breeding biology. Marine acoustic observatories, such as IMOS (the Integrated Marine Observing System, http://www.imos.org.au/) and PALAOA (Boebel et al. 2008), were designed to detect various marine sounds, including migrating marine mammals. Terrestrial observatories are less common, but serve the same functions as marine observatories, although the types of sounds and processes are somewhat different.

The Australian Acoustic Observatory (A2O) is a continent-wide series of sites at which passive acoustic recording of environmental sounds is taking place (Roe et al., 2021). The A2O is designed, as are other observatories, to collect data for scientific study, and the data are stored and freely available. Recording sites were selected to be representative of the spatial extent of ecoregions (Olson et al., 2001), and are placed in relatively undisturbed sites, such as parks and reserves, although some sites are grazed, and others are peri-urban (Roe et al., 2021). The recordings are intended to allow monitoring of vocal wildlife, and to determine the impact of factors such as environmental conditions on vocal behaviour of individual species, or more generally across broader groups of taxa. The presence and absence, arrivals and departures of fauna should be evident from the data collected by the A2O. In addition, population size, or species abundance can sometimes be estimated from acoustic data (Marques et al., 2013), with the methods required for this varying from relatively simple for some taxa (e.g. Lambert & McDonald, 2014), through to more challenging combinations of acoustic and other data sources (e.g. Doser et al., 2021).

Recently there has been increasing awareness of the high rates of biodiversity decline characteristic of Australia (e.g. Woinarski et al., 2015), and the world (Cardinale et al., 2012), and thus methods of reducing the rate of biodiversity decline have become a focus of research (Hernandez et al., 2021; Kearney et al., 2018). Monitoring rare species to detect declines and the success or otherwise of recovery activities, is fundamental to conservation, and acoustic recording is emerging as a cost-effective, scalable monitoring tool for fauna (e.g. Gibb et al., 2019). The A2O was not designed specifically to monitor threatened or endangered wildlife, but it might be possible to use the data it collects to monitor some threatened species, mostly because of the widespread nature of its sites, and, unfortunately, the widespread nature of threatened species in Australia. Here we examine the potential of the A2O to monitor near threatened, threatened, endangered and critically endangered species, based on their vocal behaviour, geographic distributions in relation to the sites of the A2O, and on some knowledge of habitat use. Success at monitoring threatened species would demonstrate an important use of the A2O.

MATERIALS AND METHODS

Sites of the A2O, including GPS locations, are available at https://acousticobservatory.org/sites/. There are 86 locations, each with four recorders. Recorders are deployed in pairs, one in a wet area and one in a dry area. They are positioned between 500 and 5000 m apart (most between 500

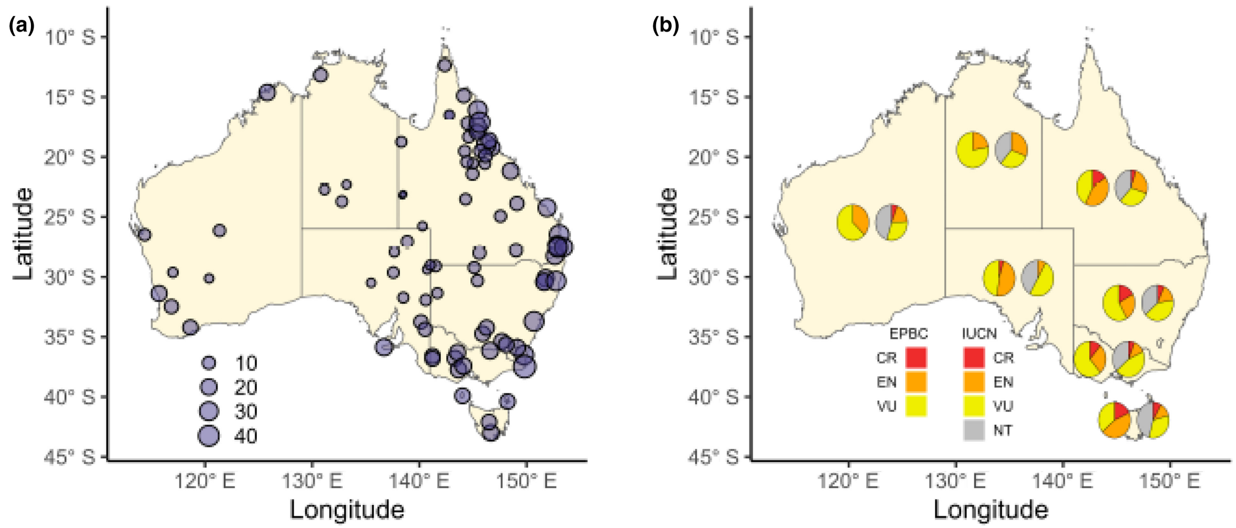

FIGURE 1 (a) Map of the 86 sites of the Australian Acoustic Observatory (https://acousticobservatory.org) and the number of vocal threatened species they could conceivably detect, and (b) the proportion of species belonging to each threatened category (CR, critically endangered; EN, endangered; NT, near-threatened; VU, vulnerable.) that can be detected in each Australian state.

and 1000 m), close enough to monitor the same broad area, but far enough apart that they can be treated as independent samples.

The acoustic recorders are a proprietary design (https://www.frontierlabs.com.au/solar-bar), and record in mono at 16-bit 22 050 Hz with FLAC lossless compression in 2-h file blocks stored on PNY Elite-X SDXC 512 GB SD cards. The 22 KHz sample rate enables representation of signals up to 11 KHz, capturing most bird, mammal and insect sounds, although not the ultrasonic calls of bats. Recording schedule is 24 h per day 7 days a week. Further details on the recorders and recording is available in (Roe et al., 2021).

We compiled a list of vocal near-threatened, vulnerable, endangered and critically endangered Australian species, using the IUCN (International Union for the Conservation of Nature) Red List (https://www.iucnredlist.org/). We also obtained listings from the EPBC Act (Environmental Protection and Biodiversity Conservation Act) of vulnerable, endangered and critically endangered species from EPBC Act List of Threatened Fauna (https://www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl).

For each list of species (IUCN & EPBC), we obtained species distribution maps from the relative listing authority (BirdLife International & Handbook of the Birds of the World, 2022; IUCN, 2022), as each source lists species in some different threatened categories and uses somewhat different expected distributions. Using the most conservative distribution ranges from each data source ('extant' for the IUCN, 'Species or species habitat likely to occur' for the EPBC), we determined which A2O sites fell within the distribution ranges of each species, such that it was theoretically possible that we could hear a species, based on the location of the site.

TABLE 1 The number of vocal 'threatened' species that could be monitored by sites of the Australian Acoustic Observatory broken down by taxonomic class, listing category and listing authority.

Class	Number species detectable	Critically endangered (IUCN/EPBC)	Endangered (IUCN/EPBC)	Vulnerable (IUCN/EPBC)	Near threatened (IUCN)
Amphibia	28	2/3	9/6	8/8	2
Aves	112	5/6	9/29	22/42	22
Mammalia	31	1/0	6/13	7/13	8
Total	171	8/9	24/48	37/63	32

To quantify the range of threatening processes impacting the species we may be able to monitor, we examined the threats impacting all IUCN listed species according to the IUCN Threats Classification Scheme (Version 3.3; https://www.iucnredlist.org/resources/threat-classification-scheme). We determined the number of species impacted by each primary threat category across the three vocal taxonomic classes that we can monitor acoustically using the A2O (most Amphibia, Aves, and some Mammalia). The only threatened invertebrates listed for Australia were not vocal.

We also consulted the governmental approved conservation advice for each threatened species listed on the EPBC, and determined whether monitoring was listed as a priority for the conservation of the species.

RESULTS

We found that, based on distribution maps, all 86 of the Australian Acoustic Observatory sites could potentially harbour vocal threatened species, and thus could potentially aid in the conservation of up to 171 species (Table 1; Appendix S1).

The sites of the A2O, although selected for other reasons, that is, because they were representative of ecoregions, or moderately undisturbed, or both, were likely to detect critically endangered, endangered, vulnerable and near threatened species. In particular, a number of individual sites along the east coast (home to many endangered species) may detect up to 40 species (Figure 1a). Even in Western and Central Australia, where there are many fewer sites, more than 15 species may be detected at single sites (Figure 1a). Despite a much higher concentration of A2O sites in the eastern states of Australia, there is still potential to monitor critically endangered species in all states except the Northern Territory (Figure 1b). In addition, some of the species we list as possibly detectable in recordings, have already been incidentally detected in the audio data for six sites where we are conducting on-ground surveys, which are Rinyurru, Undara, Wambiana, Mourachan, Duval and Tarcutta (Allen-Ankins et al., 2023). Using monitoR templates (Katz et al., 2016), we have detected koalas (*Phascolarctos cinereus*; Mt. Duval), Gang-gang Cockatoos (*Callocephalon fimbriatum*; at Tarcutta) and Squatter Pigeons (*Geophaps scripta*; at Wambiana, Undara and Rinyuru) and using Kaleidoscope Pro 5.1.8. (Wildlife Acoustics, https://www.wildlifeacoustics.com) we have detected Swift Parrots (*Lathamus discolour*; at Tarcutta; SAA, pers. obs.). We have also detected Red-tailed Black Cockatoos (*Calyptorhynchus banksii*) using monitoR templates, but not the endangered subspecies.

We also compiled the threats influencing each IUCN listed species and found that the species we can potentially monitor are impacted by 10 out of the 12 primary threat categories on the IUCN Threats Classification Scheme (only 'Geological events' & 'Other options' not represented; Figure 2).

Of the 120 EPBC listed species, 85 had government-approved conservation advice. Almost all conservation advices examined (83/85) had activities listed under 'Survey and monitoring priorities' and/or 'Research priorities' to which acoustic monitoring using the A2O could contribute (Appendix S2).

DISCUSSION

We found that, although it was not designed expressly for the purpose, the A2O has the potential to detect and monitor a wide range of Australia's threatened amphibians, birds and mammals. Although the observatory

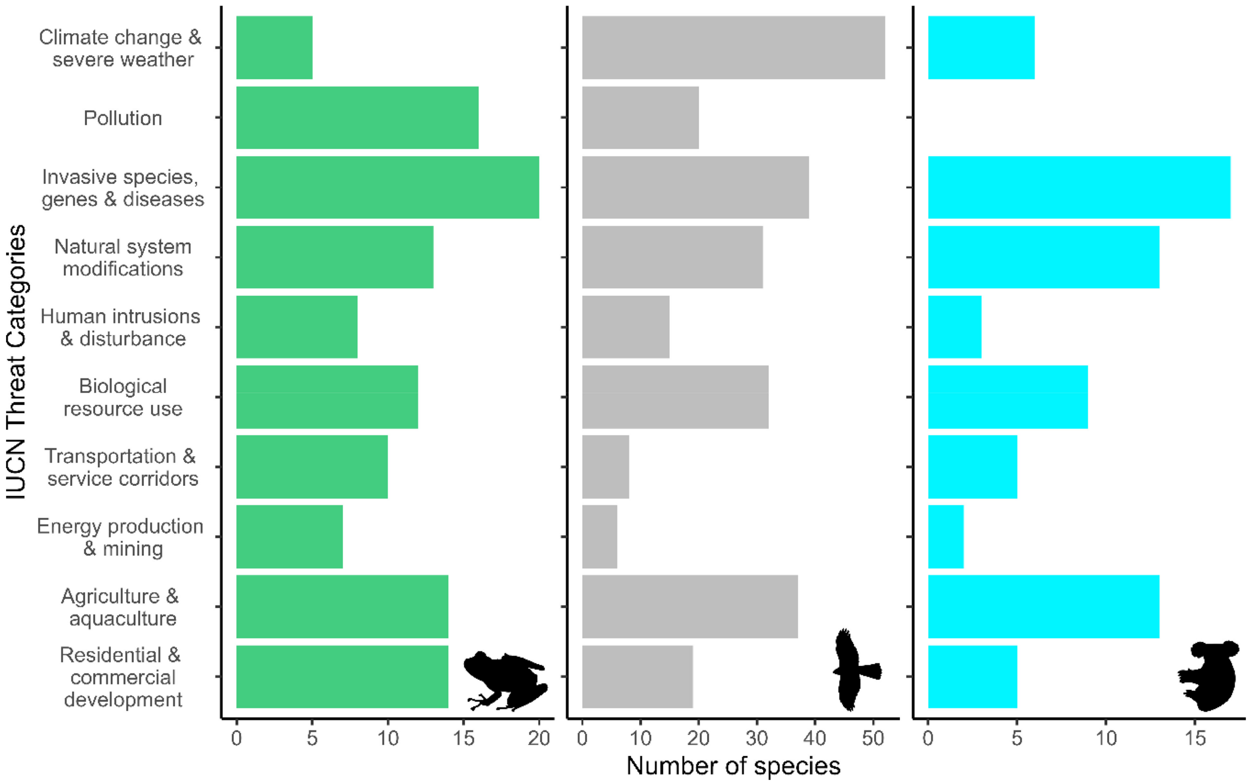

FIGURE 2 The number of amphibians (green), birds (grey), and mammals (blue) we could potentially monitor, impacted by each of the IUCN threat categories ('Geological events' & 'Other options' not represented).

was designed to sample broadly, in moderately pristine habitats, a representative sample of Australia's six largest ecoregions (https://www.dcceew.gov.au/environment/land/nrs/science/ibra/australias-ecoregions), and the purpose of the observatory is to provide data and monitor fauna in general, for example to detect declines and movements of common species, and to allow for a range of other kinds of studies of vocal animal biology (Roe et al., 2021), the A2O may also aid in conservation of endangered species. The observatory has already detected several threatened species in several locations, specifically in areas where these detections were verified by visual observations, where we are carrying out ground-truthing biodiversity surveys, and thus in locations where we were specifically searching the data for species based on both species distributions and observations (Allen-Ankins et al., 2023). Targeted screening of data by creation and use of supervised and unsupervised machine learning algorithms, or using citizen science or combinations of these techniques, and other focussed study designed to search all sites for calls will reveal other species at other sites, and the efficacy and efficiency of automated acoustic analysis tools is only growing. The data compiled here serve as a critical starting point to allow searches at specific sites for species of interest.

What is the value of detecting a species at a site using A2O data? Threatened species are often rare, and difficult to detect with periodic surveys or other searches. The A2O sensors are designed to record all the time, thus, possibly, increasing the likelihood of detecting species over other, more temporally fleeting methods of detection such as surveys (e.g. Tegeler et al., 2012). Detecting a species verifies its presence, and allows for further research on abundance, habitat use, movement and other basic biological knowledge that can be critical for conservation. In addition, the long-term nature of sampling provided by the A2O (on the scale of years) increases the likelihood that arrivals and departures can be recorded, tracked and correlated with a range of both predictable and more stochastic events, such as seasonal changes, storms, anthropogenic development, floods and fires.

There is also value in failing to detect a species at a site, especially one where we expect that species to occur (e.g. MacKenzie et al., 2003). If a species appears to be absent in the audio data in a locale where we expect it, it is possible to take further action to search for it, including manual searches, establishing more recording points or using other methods such as camera traps or eDNA, if appropriate. In addition, continuing to search the acoustic data over a longer period may increase detectability. Finally, such data could be used to clarify patterns of disappearance (and, hopefully, reappearance) for nomadic or migratory species. Ultimately, rebound and recovery of threatened taxa across former ranges could also be quantified in this way. Compared to many other sampling methods, audio data allow us to sample when no humans are present, potentially increasing detection of sensitive or rare species over methods that require more frequent site visits.

It is important to acknowledge that, even though this study only considers species and sites where distribution maps indicate the species is 'likely to occur', it is very possible that our sites are not located in the right micro-habitat required to detect a particular species that may occur across that broader area. Thus, recorders placed in inappropriate habitat may hamper detection of some of the species we list here. Many threatened species are rare or threatened because they prefer restricted habitats. The sheer number of species that could potentially be detected at each site, however, strongly suggests that the A2O recorders are likely to reliably detect at least some threatened species, and provide some information on their whereabouts, and their frequency of occurrence at the site. Both detections and failures to detect species can be followed up with other detection methods to clarify the meaning and usefulness of detections. Detailed habitat notes on the specific conditions in the near vicinity of each sensor (Roe et al., 2021) allow these details to be assessed for researchers seeking to monitor specific taxa before searching the audio data. Importantly, these gaps in coverage for specific species, as well as areas such as the Northern Territory identified herein, allow clear identification of priorities for locations of new sensors augmenting the current A2O.

We found that species at the sites were likely to be affected by a range of threats, including 10 of the 12 primary threat categories listed by the IUCN. Threats affecting the identified threatened species are likely to be the cause of future declines in species that are not yet in trouble. Knowledge of the threats in relation to location is useful, as they could be used to identify other sensitive species, or as recommendations for mitigation. The A2O provides a potential feedback loop, in which the success of attempts at mitigation could be assessed by monitoring for species influenced by particular threats at a range of scales across management implementations impacting the observatory footprint.

While there is a lot of potential for the A2O to successfully detect the presence/absence of species, site occupancy and even movement(s) if species are migratory or detected in new areas, at the moment detecting population declines using this method will rely principally on detecting declines in site occupancy, rather than detecting declines in abundance. It is possible to correctly estimate abundance from the numbers of calls for birds (Marques et al., 2013; Pérez-Granados & Traba, 2021), but most studies rely on carefully validated single-species comparisons with human point-counts, and even then not all such studies (3/20 reviewed) find significant relationships between point count estimations of abundance and call number [although 17/20 did, reviewed by Pérez-Granados & Traba (2021)]. Other methods to estimate abundance from acoustic recording require more intensive efforts, such as microphone arrays, and stereo recording [reviewed by Pérez-Granados & Traba (2021)]. Arguably, even detections of reduced site occupancy would be useful for monitoring threatened species, and the long-term and continuous nature of recording by the A2O may allow for some of the ground-truthing necessary to assess abundance in some species, although this is not being done at the moment.

In general, we found that a tool designed to monitor species more broadly will be useful for monitoring threatened species once more tools to analyse data have been developed, providing a potentially important opportunity for government bodies and other agencies not only to both use and better understand the distribution of rare and threatened species but also to fulfil the monitoring obligations and advance progress towards recommended conservation activities. Future work should focus on developing and deploying modern automated acoustic analysis tools to leverage this observatory resource, as well as identifying lacunae in coverage for future infrastructure deployments.

AUTHOR CONTRIBUTIONS

Lin Schwarzkopf: Conceptualization (equal); funding acquisition (equal); investigation (equal); project administration (equal); supervision (equal); writing – original draft (equal). **Paul Roe:** Conceptualization (equal); funding acquisition (equal); project administration (equal); writing – review and editing (equal). **Paul G. McDonald:** Conceptualization (equal); funding acquisition (equal); project administration (equal); writing – review and editing (equal). **David M. Watson:** Conceptualization (equal); funding acquisition (equal); project administration (equal); writing – review and editing (equal). **Richard A. Fuller:** Conceptualization (equal); funding acquisition (equal); methodology (equal). **Slade Allen Ankins:** Conceptualization (equal); data curation (equal); formal analysis (equal); investigation (equal); methodology (equal); writing – original draft (equal).

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DATA AVAILABILITY STATEMENT

Data are available as excel files in appendices S1 and S2.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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