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Short Communication

Comparison of point counts and automated acoustic monitoring: detecting birds in a rainforest biodiversity survey

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Abstract. To monitor assemblages of animals, ecologists need effective methods for detecting and recording the distributions of species within target areas in restricted periods of time. In this study, we compared the effectiveness of a traditional avian biodiversity assessment technique (point counts) with a relatively new method (automated acoustic recordings) along an elevational gradient in rainforest in central Queensland, Australia. On average, point counts detected more species than acoustic recordings of an equivalent length of time ($n = 40$, $P = <0.001$). We suggest these results are driven by the visual detection of additional species during point counts. Despite the fact that point counts detected more species than acoustic recordings, datasets generated by both methods showed similar patterns in the community response to change in elevation. There was significant overlap in the species detected using both methods, but each detected several unique species. Consequently, we recommend the use of both techniques in tandem for future biodiversity assessments, as their respective strengths and weaknesses are complementary.

Additional keywords: Eungella National Park, point counts, rainforest bird diversity.

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Introduction

Traditionally, point counts have been the most commonly used method to rapidly assess the avian biodiversity of an area (Celis-Murillo *et al*. 2009; Venier *et al*. 2012). There are, though, several problems with point counts: in areas with high species richness, observers may be 'swamped' and fail to record some species (Haselmayer and Quinn 2000); differences in skill between observers may manifest as inter-observer effects (Hobson *et al*. 2002; Celis-Murillo *et al*. 2009); there may be a lack of trained personnel to conduct surveys (Holmes *et al*. 2014); birds may respond to the observers presence (Digby *et al*. 2013); and the cost of extended fieldwork necessary to build long-term datasets is often prohibitive (Thomas and Marques 2012). In recent years, technological advances have led to the development of automated acoustic recorders that may prove an effective, low-cost way of monitoring biodiversity over large spatial and temporal scales (Thomas and Marques 2012; Wimmer *et al*. 2013).

In avian biology, acoustic recorders have been primarily used for the detection of rare, poorly-known or elusive species (Goyette *et al*. 2011; McGuire *et al*. 2011; Buxton and Jones 2012; Zwart *et al*. 2014), but also for the identification of individuals within a population (Laiolo *et al*. 2007; Grava *et al*. 2008), behavioural studies (Mennill 2011; Osmun and Mennill 2011), detection of migrating birds (Farnsworth and Russell 2007) and community-level diversity studies (Haselmayer and Quinn 2000; Rempel *et al*. 2005; Wimmer *et al*. 2013). Some advantages of acoustic recordings are the creation of a permanent record for later analysis (or reanalysis), removal of observer bias, minimisation of disturbance, potential increases in the scale of monitoring schemes and the ability to sample more easily in difficult conditions (Hobson *et al*. 2002; Mennill *et al*. 2012; Rempel *et al*. 2013; Holmes *et al*. 2014). So far, the use of acoustic recorders to monitor avian biodiversity in Australia has been limited (but see Cai *et al*. 2007; Wimmer *et al*. 2013) and has taken place only in open forest habitats.

Previous comparisons between acoustic recordings and traditional techniques have most commonly found no significant difference between methods with regards to the number of species or individuals detected (Table 1). However, the majority of these studies have been conducted in temperate regions. Given the challenges associated with detecting birds in rainforests (Anderson 2011), and the lack of previous studies in Australia, we aimed to determine whether acoustic recorders deployed in subtropical Australian rainforest could be used to generate a dataset comparable to one generated using

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Table 1. Relative performance of automated acoustic recorders (ARs) versus traditional methods in previous studies

Traditional methods varied among studies but included call counts (Digby *et al.* 2013), call playback (McGuire *et al.* 2011), area searches (Wimmer *et al.* 2013) and a variety of methods based on point counts (remaining studies). Equivalent effort refers to whether the same amount of time was allocated to ARs and the alternative method during the study

Authors	Equivalent effort?	Target	Better performing method?
Haselmayer and Quinn (2000)	Yes	Community	Equal performance
Hobson *et al.* (2002)	Yes	Community	Equal performance
Acevedo *et al.* (2009)	No	Community	Acoustic recordings
McGuire *et al.* (2011)	No	One species	Equal performance
Celis-Murillo *et al.* (2012)	Yes	Community	Equal performance
Venier *et al.* (2012)	Yes	Community	Traditional method (distance point count)
Digby *et al.* (2013)	Yes	One species	Equal performance
Wimmer *et al.* (2013)	No	Community	Acoustic recordings
Holmes *et al.* (2014)	No	Three species	Equal performance
Klingbeil and Willig (2015)	Yes	Community	Traditional method (point count)
Sedláček *et al.* (2015)	Yes	Community	Equal performance

point counts. A secondary aim was to assess whether this dataset would be suitable for analysis of community-level ecological patterns.

Methods

Study site

Field work was conducted in two sessions: between 4 November and 1 December 2013 and between 19 March and 15 April 2014 in Eungella National Park (21°1’48"S, 148°38’23"E) and Pelion State Forest (21°3’36"S 148°40’48"E), ~80 km west of Mackay on the central Queensland coast. The first sampling session was at the beginning of the wet season and the second at the conclusion. The average annual rainfall in the region is 2199.1 mm (Dalrymple Heights weather station, see http://www.bom.gov.au/climate/data/index.shtml), and the average daily maximum temperature between the sampling periods was 31.6°C (temperature was recorded at three sites per elevation using iButtons (DS21 Thermochron® iButton®, Maxim Integrated, CA, USA)). In general, the vegetation of the survey locations can be classified as complex notophyll vine forest (Tracey 1982).

We established a total of 24 sites along a gradient that encompassed the full elevational distribution of rainforest in the study area; four replicate sites in each of six elevational bands of ~200, 400, 600, 800, 1000 and 1200 m above sea level (±56 m), in a design broadly similar to that of Kitching *et al.* (2011). Replicate sites within each band were separated by at least 400 m, with some sites up to 5 km distant. At each site a 20 × 20-m permanently marked quadrat was established.

Point counts

The researcher EL conducted two 10-min point counts at each site, in the morning and afternoon, in each sampling session. Morning counts were undertaken as close as possible to dawn and afternoon counts in the 3 hours before sunset. The occurrence of all bird species seen or heard at the site during the count period was recorded, but counts of individual birds were not. Morning and afternoon count data were pooled before analysis. Due to inclement weather, counts at the 1200-m sites in 2013 were only partially completed.

Automated audio recordings

Each of the replicate sites was sampled using a Songmeter SM2+ (unit described in Mennill *et al.* (2012)) placed in a central position within the 20 × 20-m quadrat in both the 2013 and 2014 sampling sessions. Songmeters were programmed to record for 2.5 h in the morning (beginning 20 min before dawn) and for 2 h in the afternoon (programmed to finish recording at sunset) at factory default settings.

To compare recordings with point counts, EL listened to five randomly selected 2-min sections from each recording and noted all bird species heard. If ambient environmental noise (e.g. from rain) was too loud to identify the birds that were calling, a different section of the recording was chosen. This generated a dataset that was directly comparable (in terms of elapsed time) to that of the point count data.

Data analysis

Initially we were interested in whether point counts or acoustic recordings were more effective at detecting species. Rather than compare the mean number of species recorded by each method, since species richness was likely to vary between sites and elevations, we compared the mean proportions of the total species detected at the sites. For each sampling occasion we pooled the available data from both methods at each site ($n = 40$), calculated the proportions of the total species that were detected by each method, and compared their means using a one-way analysis of variance (ANOVA).

We also investigated elevational patterns of community composition shown by each method and the results of both methods combined. To investigate these we first pooled data from both methods and sampling sessions to create a dataset based on the presence or absence of species at each site. Using the package Plymouth Routines in Multivariate Ecological Research (PRIMER 6™, http://www.primer-e.com/, verified 9 March 2016; Clarke and Gorley 2006), non-metric multi-dimensional scaling

(NMDS) ordinations were generated to visualise elevational patterns displayed by bird assemblages. Three separate ordinations were generated based on data from point counts, acoustic recordings or both methods combined. Ordinations were generated from matrices of pairwise comparisons between sites, based on Sørensen's similarity index values with 999 permutations. We examined the relationship between the compositional turnover in bird assemblages and elevation by plotting the Sørensen similarity values between all pairs of sites against the difference in elevation between the sites. Separate graphs were generated for the three datasets; point counts, acoustic recordings and the combined methods (see Fig. 1). The relationship between

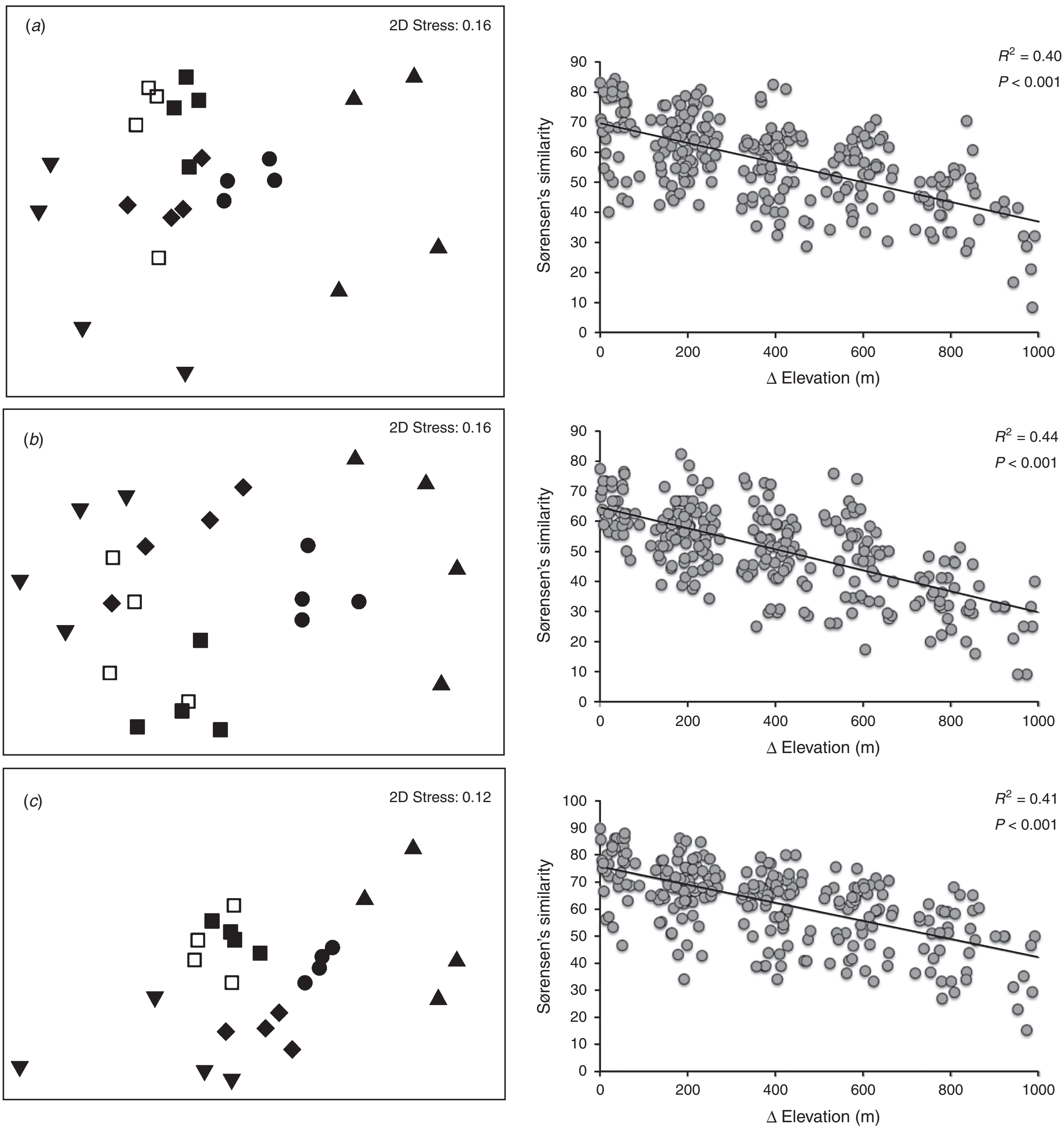

Fig. 1. Non-metric multidimensional scaling ordinations (left) and graphs of Sørensen similarity between all possible pairs of sites plotted against the difference in elevation between site pairs for (*a*) point counts (*b*) recordings and (*c*) both methods combined. In all ordinations: inverted triangles 200-m sites; open squares 400-m sites; closed squares 600-m sites; diamonds 800-m sites; circles 1000-m sites; and triangles 1200-m sites.

community similarity and elevational distance was assessed using simple linear regression.

Results

A total of 60 species were detected in our study: 50 species by point counts and 45 by recordings. Of these, 36 species were detected by both methods (Sørensen's similarity index value of 0.774). Point counts detected 14 unique species (of which six were recorded only once), and recordings detected eight unique species (of which three were detected once). There were more overall detections in the first sampling occasion (943; November–December 2013) than in the second (735; March 2014). On average, point counts detected a significantly greater proportion of the total species present at a site than acoustic recordings across all sites ($n = 40$, $P = <0.001$).

Ordinations based on all three datasets, point counts (Fig. 1*a*), acoustic recordings (Fig. 1*b*) and both methods combined (Fig. 1*c*) showed clear elevational stratification of avian assemblages. In all cases low elevation and highland sites were located at opposite sides of the ordination panes. All three datasets showed that as the elevational distance between a pair of sites increased, community similarity decreased (point counts ($R^2 = 0.40$, $P = <0.001$); recordings ($R^2 = 0.44$, $P = <0.001$); combined ($R^2 = 0.41$, $P = <0.001$)), indicating significant turnover in community composition with changing elevation.

Discussion

In this study, we found that point counts detected significantly more species than acoustic recordings across an elevational gradient in subtropical rainforest. The detection of 'quiet' species from visual cues during point counts was at least partially responsible for this result. Obviously, only species that vocalise can be detected by acoustic recorders (Laiolo 2010; Mennill *et al*. 2012). Due to the short duration of our study we also had limited recordings to work with. As an example, increased ambient noise from water flow in a nearby creek at the conclusion of the wet season in 2014 made analysis of the recordings from some 200-m sites difficult.

Despite these challenges, we found no differences in the community-level patterns (elevational stratification and turnover in species composition with increasing elevational distance between sites) that were generated by data from the two methods (see Fig. 1). While a direct comparison between methodologies was the focus of this study, we must acknowledge that it is unusual for acoustic recordings to be so short. Indeed, the main advantage of using acoustic recorders is that they can be left *in situ* for long periods (Klingbeil and Willig 2015). Increasing the recording duration will increase the number of species detected but leads to longer processing time when automatic processing is not possible (Wimmer *et al*. 2013).

In this study, the first of its kind in Australia, we have demonstrated that it is possible to generate a dataset suitable for the analysis of community-level patterns in birds using acoustic recorders. From a management perspective, this is encouraging; advances in technology and manufacturing are leading to the development of significantly cheaper and more efficient bioacoustic recorders and it is now theoretically possible to have a large number of these devices installed at monitoring stations year-round. However, the need to manually process the recordings, the adverse effects that the weather and the ambient acoustic environment can have on recording quality, the cost of equipment and hardware problems are all weaknesses of automated acoustic monitoring that must be considered in future projects. Another potential issue, the inability to accurately generate abundance or density data from acoustic recordings, may be compensated for by using point counts to target certain species or areas of interest. We found that a combination of point counts and acoustic recordings detected more species than either method alone, and that each method contributed several unique species to the pooled dataset.

The permanent record of a community generated by acoustic recording allows for the re-analysis of the data using novel techniques in the future (Sedláček *et al*. 2015). Each time a recording of a community is made, it has the potential to become part of a larger dataset for future analysis. As climate change and habitat fragmentation continue to threaten avian communities worldwide (Şekercioğlu *et al*. 2008; Bregman *et al*. 2014) and in Australia (Anderson *et al*. 2013; Garnett and Franklin 2014), the baseline data generated by current acoustic recordings may assist in the assessment of future impacts. Acoustic recorders are becoming an important tool for ecological research and monitoring, and we recommend their use alongside traditional methods of biodiversity assessment in the future.

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References

Acevedo, M. A., Corrada-Bravo, C. J., Corrada-Bravo, H., Villanueva-Rivera, L. J., and Aide, T. M. (2009). Automated classification of bird and amphibian calls using machine learning: a comparison of methods. *Ecological Informatics* **4**(4), 206–214. doi:10.1016/j.ecoinf.2009.06.005

Anderson, A. S. (2011) Influences of the past, present and future climate on the structure and diversity of rainforest bird assemblages in north-eastern Australia. Ph.D. Thesis, James Cook University, Townsville

Anderson, A. S., Storlie, C. J., Shoo, L. P., Pearson, R. G., and Williams, S. E. (2013). Current analogues of future climate indicate the likely response of a sensitive montane tropical avifauna to a warming world. *PLoS One* **8**(7), e69393. doi:10.1371/journal.pone.0069393

Bregman, T. P., Şekercioğlu, Ç. H., and Tobias, J. A. (2014). Global patterns and predictors of bird species responses to forest fragmentation: implications for ecosystem function and conservation. *Biological Conservation* **169**, 372–383. doi:10.1016/j.biocon.2013.11.024

Buxton, R. T., and Jones, I. L. (2012). Measuring nocturnal seabird activity and status using acoustic recording devices: applications for island restoration. *Journal of Field Ornithology* **83**(1), 47–60. doi:10.1111/j.1557-9263.2011.00355.x

Cai, J., Ee, D., Pham, B., Roe, P., and Zhang, J. (2007) Sensor network for the monitoring of ecosystem: bird species recognition. Available at http://eprints.qut.edu.au/11227/1/11227a.pdf [Verified 9 March 2016].

Celis-Murillo, A., Deppe, J. L., and Allen, M. F. (2009). Using soundscape recordings to estimate bird species abundance, richness, and composition. *Journal of Field Ornithology* **80**(1), 64–78. doi:10.1111/j.1557-9263.2009.00206.x

Celis-Murillo, A., Deppe, J. L., and Ward, M. P. (2012). Effectiveness and utility of acoustic recordings for surveying tropical birds. *Journal of Field Ornithology* **83**(2), 166–179. doi:10.1111/j.1557-9263.2012.00366.x

Clarke, K. R., and Gorley, R. N. (2006) 'PRIMER v6: User Manual/Tutorial.' (Primer-E Ltd.: Plymouth)

Digby, A., Towsey, M., Bell, B. D., and Teal, P. D. (2013). A practical comparison of manual and autonomous methods for acoustic monitoring. *Methods in Ecology and Evolution* **4**(7), 675–683. doi:10.1111/2041-210X.12060

Farnsworth, A., and Russell, R. W. (2007). Monitoring flight calls of migrating birds from an oil platform in the northern Gulf of Mexico. *Journal of Field Ornithology* **78**(3), 279–289. doi:10.1111/j.1557-9263.2007.00115.x

Garnett, S., and Franklin, D. (Eds) (2014) 'Climate Change Adaptation Plan for Australian Birds.' (CSIRO Publishing: Melbourne, Vic.)

Goyette, J. L., Howe, R. W., Wolf, A. T., and Robinson, W. D. (2011). Detecting tropical nocturnal birds using automated audio recordings. *Journal of Field Ornithology* **82**(3), 279–287. doi:10.1111/j.1557-9263.2011.00331.x

Grava, T., Mathevon, N., Place, E., and Balluet, P. (2008). Individual acoustic monitoring of the European Eagle Owl *Bubo bubo*. *The Ibis* **150**(2), 279–287. doi:10.1111/j.1474-919X.2007.00776.x

Haselmayer, J., and Quinn, J. S. (2000). A comparison of point counts and sound recording as bird survey methods in Amazonian southeast Peru. *The Condor* **102**(4), 887–893. doi:10.1650/0010-5422(2000)102[0887:ACOPCA]2.0.CO;2

Hobson, K. A., Rempel, R. S., Hamilton, G., Turnbull, B., and Van Wilgenburg, S. L. (2002). Acoustic surveys of birds using electronic recordings: new potential from an omnidirectional microphone system. *Wildlife Society Bulletin* **30**(3), 709–720.

Holmes, S. B., McIlwrick, K. A., and Venier, L. A. (2014). Using automated sound recording and analysis to detect bird species-at-risk in southwestern Ontario woodlands. *Wildlife Society Bulletin* **38**(3), 591–598. doi:10.1002/wsb.421

Kitching, R., Putland, D., Ashton, L. A., Laidlaw, M. J., Boulter, S., Christensen, H. S., and Lambkin, C. L. (2011). Detecting biodiversity changes along climatic gradients: the IBISCA-Queensland Project. *Memoirs of the Queensland Museum: Nature* **55**(2), 235–250.

Klingbeil, B. T., and Willig, M. R. (2015). Bird biodiversity assessments in temperate forest: the value of point count versus acoustic monitoring protocols. *PeerJ* **3**, e973. doi:10.7717/peerj.973

Laiolo, P. (2010). The emerging significance of bioacoustics in animal species conservation. *Biological Conservation* **143**(7), 1635–1645. doi:10.1016/j.biocon.2010.03.025

Laiolo, P., Vögeli, M., Serrano, D., and Tella, J. L. (2007). Testing acoustic versus physical marking: two complementary methods for individual-based monitoring of elusive species. *Journal of Avian Biology* **38**(6), 672–681. doi:10.1111/j.2007.0908-8857.04006.x

McGuire, A., Johnston, G., Robertson, J., and Kleindorfer, S. (2011). Comparison of survey methods for detection of the elusive Western Whipbird *Psophodes nigrogularis* with notes on its distribution. *South Australian Ornithologist* **37**(2), 49–59.

Mennill, D. J. (2011). Individual distinctiveness in avian vocalizations and the spatial monitoring of behaviour. *The Ibis* **153**(2), 235–238. doi:10.1111/j.1474-919X.2011.01119.x

Mennill, D. J., Battiston, M., Wilson, D. R., Foote, J. R., and Doucet, S. M. (2012). Field test of an affordable, portable, wireless microphone array for spatial monitoring of animal ecology and behaviour. *Methods in Ecology and Evolution* **3**(4), 704–712. doi:10.1111/j.2041-210X.2012.00209.x

Osmun, A. E., and Mennill, D. J. (2011). Acoustic monitoring reveals congruent patterns of territorial singing behaviour in male and female tropical wrens. *Ethology* **117**(5), 385–394. doi:10.1111/j.1439-0310.2011.01887.x

Rempel, R. S., Hobson, K. A., Holborn, G., Van Wilgenburg, S. L., and Elliott, J. (2005). Bioacoustic monitoring of forest songbirds: interpreter variability and effects of configuration and digital processing methods in the laboratory. *Journal of Field Ornithology* **76**(1), 1–11. doi:10.1648/0273-8570-76.1.1

Rempel, R. S., Francis, C. M., Robinson, J. N., and Campbell, M. (2013). Comparison of audio recording system performance for detecting and monitoring songbirds. *Journal of Field Ornithology* **84**(1), 86–97. doi:10.1111/jofo.12008

Sedláček, O., Vokurková, J., Ferenc, M., Djomo, E. N., Albrecht, T., and Hořák, D. (2015). A comparison of point counts with a new acoustic sampling method: a case study of a bird community from the montane forests of Mount Cameroon. *Ostrich* **86**, 213–220. doi:10.2989/00306525.2015.1049669

Şekercioğlu, Ç. H., Schneider, S. H., Fay, J. P., and Loarie, S. R. (2008). Climate change, elevational range shifts, and bird extinctions. *Conservation Biology* **22**(1), 140–150. doi:10.1111/j.1523-1739.2007.00852.x

Thomas, L., and Marques, T. A. (2012). Passive acoustic monitoring for estimating animal density. *Acoustics Today* **8**(3), 35–44. doi:10.1121/1.4753915

Tracey, J. G. (1982) 'The Vegetation of the Humid Tropical Region of North Queensland.' (CSIRO: Melbourne, Vic.)

Venier, L. A., Holmes, S. B., Holborn, G. W., McIlwrick, K. A., and Brown, G. (2012). Evaluation of an automated recording device for monitoring forest birds. *Wildlife Society Bulletin* **36**(1), 30–39. doi:10.1002/wsb.88

Wimmer, J., Towsey, M., Roe, P., and Williamson, I. (2013). Sampling environmental acoustic recordings to determine bird species richness. *Ecological Applications* **23**(6), 1419–1428. doi:10.1890/12-2088.1

Zwart, M. C., Baker, A., McGowan, P. J. K., and Whittingham, M. J. (2014). The use of automated bioacoustic recorders to replace human wildlife surveys: an example using nightjars. *PLoS One* **9**(7), e102770. doi:10.1371/journal.pone.0102770