**Discussion**

Acoustic monitoring has the potential to be a powerful tool to monitor vertebrate biodiversity at large temporal and spatial scales, but reliable analysis methods that have been validated with on ground-surveys are needed to take advantage of large acoustic datasets. We examined the relationship between 13 acoustic indices and biodiversity estimates of various vertebrate taxonomic groupings and found a number of individual acoustic indices had moderate to strong correlations with species richness and total count, but had comparatively poor correlations with Shannon’s diversity. Models incorporating multiple acoustic indices outperformed individual indices and were able to predict species richness of all vertebrates and birds with reasonable accuracy, but performed relatively poorly for non-avian vertebrates and frogs. Additionally, site-specific models suggest that it may be possible to monitor for fine-scale changes in species richness using acoustic indices.

**Interesting results:**

While results have been mixed, a number of previous studies have found poor correlations between many acoustic indices and bird richness (e.g. refs). Similarly, we did not find strong correlations for many of the commonly used acoustic indices (e.g. ACI, ADI, AEI, NDSI). However, in addition to commonly used acoustic indices, we also included some acoustic indices that are not often used (ACT, EVN, LFC, MFC, HFC, CLS, SPD), three of which (CLS, SPD and MFC) were often the indices with the highest single-index correlations and the most important variables in random forest models.

NDSI: we used xx bands – which is the standard (did I use standard?), but all our sites are in natural environments with low anthropogenic noise. Additionally, many biological sounds are likely to be within the standard anthro-band.

Acoustic indices were the most useful as proxies for total vertebrate biodiversity and bird biodiversity of a site. Across our survey periods, bird richness contributed on average 62% of total vertebrate species richness, and the two biodiversity measures correlated strongly (rs = 0.89). This suggests that despite many other vertebrate taxa not vocalising and directly contributing to the soundscape, acoustic indices may still act as a reasonable proxy for estimating the total vertebrate biodiversity of a site. This may only be true in environments where vertebrates are the dominant sources of sound in the environment. Environments with diverse insect fauna (e.g. tropical environments) may reduce the correlation between acoustic indices and total vertebrate diversity (Eldridge et al. 2018).

Cluster count (CLS), spectral density (SPD), and mid-frequency cover (MFC) were the three best performing acoustic indices for bird biodiversity. All three indices are calculated using the 1-8 kHz frequency range which captures the frequency range occupied by most bird species (Towsey 2017 ref).

Cluster count (CLS) and spectral density (SPD) performed best for species richness as they increase with …

Whereas MFC was the individual acoustic index with the highest correlation with bird total count and the most important index from random forest models makes sense as it should increase effectively with lots of vocalisations from birds whether they are from the same species or from many different species.

(While acoustic indices have not been used to estimate the biodiversity of frogs as often as birds, previous research has shown that random forest models of multiple acoustic indices can be reliable predictors of species level calling behaviour of various frogs at short time scales (e.g. 1 minute; Brodie et al. 2020). However, in general, acoustic indices performed poorly as proxies for frog biodiversity in this study (i.e. low correlations, poorer performing random forest models). As a vertebrate taxa known for conspicuous vocalization this result is surprising. One likely reason for this poor performance is that a large number of surveys found low or no frog diversity during the week long surveys. A number of the sites examined are located in tropical savannah environments where frog chorusing activity is strongly associated with rainfall events (Woinarski et al. 1999refs). As surveys were conducted outside the rainy season … (wrong season – further work during peak frog chorusing season should be carried out to determine whether indices may be useful during those times). Previous studies on acoustic indices and frogs – acoustic indices (ACI, H, Hf, Ht, ADI, AEI, BI) had poor correlation with anuran richness (Moreno-Gómez et al. 2019) – of those same indices tested here we also found low correlations – however, the two indices with highest correlations in the present study, MFC and SPD, were not used by Moreno-Gómez et al. 2019; ). Further study should examine whether acoustic indices may perform well for frogs at appropriate times of the year (e.g. the rainy season), particularly those indices that worked well for birds as they have not been examined before, and most frog vocalisations also occupy the same 1-8 kHz frequency band as birds.

Despite the study sites examined spanning a very large latitudinal gradient (>20 degrees of latitude), indices performed well? (sites had distinct communities?). Most prior studies examining the relationship between acoustic indices and biodiversity have done so using sites much closer in space (is this true?) …

Models of multiple indices also had higher performance for birds and all vertebrates . Other studies have used multiple acoustic index models with mixed results (e.g. Buxton et al. 2018; Retamosa-Izaguirre et al. 2021). This may be down to methodological differences, e.g. Buxton et al. 2018 estimated biodiversity from the audio recordings themselves, whereas Retamosa-Izaguirre et al. 2021 used bird point count surveys which includes both visual and aural detections.

Shannon’s diversity correlated with individual indices the worst, rf models also performed poorly – why? (similar values of Shannon’s diversity may be the result of very different numbers of species?)

Our models performed well (better than Retamosa-Izaguirre et al. 2021) (not as well as Buxton et al. 2018 – although they determined biodiversity metrics from the audio recordings themselves as opposed to the manual surveys used here),

Our approach to estimating vertebrate biodiversity differs to most other studies (e.g. Eldridge et al. and Buxton et al.), where the audio recordings themselves are manually listened to in order to estimate species richness or the number of sounds (CHECK THIS!).

Indices that performed best, both as individual indices with high correlations with biodiversity, and as important variables in random forest models, were those that …

The results of this study suggest that large-scale ecological monitoring networks such as the Australian Acoustic Observatory (A2O) can utilise acoustic indices for rapid estimates of vertebrate biodiversity, however more work is needed…

**Conclusion**

Biodiversity monitoring techniques that can be used a large temporal and spatial scales are needed…

Acoustic monitoring promises to provide.. but needs validation…

Our study found strong correlations between vertebrate diversity and specific acoustic indices at the scale of a week. Additionally, models combining multiple indices…

Further work…