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Research Paper

Do acoustic indices reflect the characteristics of bird communities in the savannas of Central Brazil?

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HIGHLIGHTS

- Bird species richness is positively related to the Acoustic Diversity Index.
- Complex habitats present higher values of Acoustic Diversity Index.
- Locations near noise sources presented a low biophony/technophony ratio.
- Proximity to highways and local roads negatively influence the NDSI index.

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ABSTRACT

Habitat loss and fragmentation represent two of the most significant threats to biodiversity. In some regions, like the Brazilian Cerrado, the deforestation rate can reach nearly 1 million hectares per year. Ecoacoustics and acoustic indices can be used to promote rapid assessments in threatened regions. We evaluated how two particular indices (the acoustic diversity index – ADI – and normalized difference soundscape index – NDSI) reflect bird species richness and composition in a protected area near Brasilia city. We hypothesised that ADI should reflect the characteristics of birds in the cerrado and in the gallery forest, i.e., with higher values in gallery forest than in the cerrado. Based on habitat structure, we also hypothesised that NDSI should be lower in less complex habitat, and lower in areas close to urbanized areas. We assessed 30 locations by installing automatic recorders to generate 15 min wave files (48 kHz, 16 bits, stereo). Manual inspection of the files revealed the presence of 107 bird species (74 in gallery forest and 47 in cerrado). Our results showed that ADI was significantly associated with species richness, being higher in gallery forest than in the cerrado. We found that NDSI values were lower in areas close to highways, an important source of impact for bird diversity. We argue that acoustic indices are a valid approach for rapid biodiversity assessment, however basic knowledge on species occurrences is essential to interpret the values provided by these indices.

1. Introduction

Biodiversity loss caused by humans is a major and challenging problem globally (Pimm, Raven, Peterson, Sekercioglu, & Ehrlich, 2006), and threats to species and ecosystems are set to continue in the future (Pereira et al., 2010). Deforestation and habitat fragmentation caused by expansion of croplands and pastures impose serious threats to species and native ecosystems, especially in South America, where the most globally significant changes in cropland expansion occurred between 1960 and 1990 (Ramankkutty, Foley, & Olejniczak, 2002). Most of cropland expansion has occurred in the Brazilian Cerrado (woodland savanna), a region, which has lost half of its original area (more than 1 million km^2) in recent decades (Brasil, 2009; Françoso et al., 2015; Klink & Machado, 2005). How biodiversity responds to habitat loss and fragmentation is one of the key topics in ecology and conservation biology (Sala et al., 2000).

Considering the rapid deforestation rate in the Brazilian Cerrado, (Brasil, 2009; Klink & Machado, 2005) it is important to develop and apply methods that can be effective for rapid biodiversity assessment. The field of Ecoacoustics, an emerging discipline that investigates spatial and temporal variation of the sounds associated with landscape structures (Sueur & Farina, 2015), may provide the answers to the ecological and conservation issues. Bioacoustics has been traditionally used in behavioural studies,

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and only recently has been applied in conservation biology (Ritts, Gage, Picard, Dundas, & Dundas, 2016; Sueur, Pavoine, Hamerlynck, & Duvail, 2008; Towsey, Parsons, & Sueur, 2014). The field of ecoacoustics, an emerging discipline that investigates spatial and temporal variation of the sounds associated with population, community or landscape structures (Sueur & Farina, 2015), may provide the answers to ecological and conservation issues.

Ecoacoustics may provide an excellent tool in conservation biology because it is non-invasive, it can synthesize a wide range of species and many locations can be surveyed simultaneously using automated recorders. In addition, the recordings can be sent to experts for thorough analysis, and data can be collected without human interference. Unlike the *in situ* observations made by researchers, recordings can provide voucher material for biodiversity inventories, creating a permanent record of a field study. The availability of analytical tools for data processing has also increased in recent years, and semi-automatic or automatic signal extraction and even identification is now possible, although there are still obstacles in automatic identification of soundscape entities. Acoustic indices for ecological studies and biodiversity monitoring are one of the automatic approaches for data analysis (Kasten, Gage, Fox, & Joo, 2012; Pieretti, Farina, & Morri, 2011; Pijanowski et al., 2011; Sueur, Farina, Gasc, Pieretti, & Pavoine, 2014), and acoustic indices can potentially be used as a surrogate for observational data when quick assessments are necessary. Another advantage of the use of acoustic indexes is to overcome the problem of analysing hours and hours of records obtained by passive recorder units.

In order to be useful, however, an acoustic index should have some congruence with the patterns of biodiversity or species diversity of the taxonomic group under investigation. If the acoustic index can be associated with species diversity or species activity, it can provide a valid tool to rapidly assess biodiversity using a soundscape approach.

The soundscape, according to Dumyahn and Pijanowski (2011), represents the entire acoustic environment of a particular landscape. In this paper, we used acoustic data to (a) characterize species richness and composition of birds associated with the Cerrado in Brazil and (b) to compare the behaviour of two indices, an acoustic diversity index (ADI) (Villanueva-Rivera, Pijanowski, Doucette, & Pekin, 2011) and the normalized difference soundscape index (NDSI) (Kasten et al., 2012) in two different Cerrado habitat types: the cerrado *stricto sensu* (in lower case to indicate the phytophysiognomy) and the gallery forest (evergreen forest-like vegetation that exists along rivers and streams).

Gallery forest is a narrow strip of forest along the rivers and streams with three vegetation layers and a closed canopy, reaching 20–25 m in height. On the other hand, the cerrado *stricto sensu* is a woodland savanna-like vegetation with sparse trees reaching 6–10 m high, with unconnected canopy coverage from 50 to 70%, allowing sunlight to directly reach the soil (Eiten, 1972; Ribeiro & Walter, 1998).

We tested predictions from three hypotheses concerning the potential associations between biodiversity data and the acoustic indices. First, we predicted that acoustic indices would reflect the characteristics of bird communities associated with the cerrado *stricto sensu* (s.s.) and gallery forest, the two habitats with highest species richness in the Cerrado biome. The basis for this prediction was that the values of the acoustic diversity index [ADI; is a measurement of the degree of acoustic complexity found at a site (see Villanueva-Rivera & Pijanowski (2014) and the Methods for details)] should be higher in gallery forest, which has greater structural complexity compared with the cerrado. Second, we predicted that the biophony/technophony ratio (i.e. the ratio of sounds produced by wildlife and by human activities respectively) should be lower in the cerrado than in gallery forest due to the higher attenuation of anthropophonic sound by the complex vegetation in gallery forest. We used the normalized difference soundscape index (NDSI) to indicate the amount of biophony relative to technophony in the two habitat types (see Gage & Axel (2014) and the Methods for more details). Finally, we predicted that the spatial arrangement of technophony noise sources such as roads, houses and buildings or airports, should influence the values of the NDSI, such that lower values would be observed near such noise sources. Thus, the NDSI would be a valid proxy for the impact of technophony on biodiversity regardless of the type of habitat (cerrado or gallery forest), and areas located close to technophony sources will have lower values of NDSI.

2. Materials and methods

2.1. Study area

We conducted this study in a protected area named the Environmental Protection Area of Gama e Cabeça do Veado (hereafter referred to as EPA), which is equivalent to the category V Protected Area Category defined by the International Union for Conservation of Nature (Phillips, 2002; Thomas & Middleton, 2003). The EPA covers 25,000 ha and was created in 1986. It is located south of Brasilia city (15° 51′16”–15° 58′ 17”, 47° 59′ 39”–47° 40′ 09” Long W) (Fig. 1), and comprises four reserves: Água Lima Farm, Roncador Ecological Reserve, Botanic Garden Ecological Station and a training centre area managed by the Brazilian Navy. In total 286 bird species have been recorded in the area (Braz & Cavalcanti, 2001), representing 33.6% of the bird species registered in the Brazilian Cerrado (Silva & Santos, 2005). The natural vegetation of the area is a mosaic of phytophysiognomies ranging from grasslands to cerrado (*s. s.*) and cerradão (tall savanna) (Eiten, 1972; Ribeiro & Walter, 1998). Along the rivers and streams there is a strip of gallery forest (up to 200 m wide) with the canopy reaching 20–25 m (Eiten, 1972).

2.2. Data collection

We established 30 sampling sites (15 in gallery forest and 15 in cerrado). The locations were separated by at least 1 km, a distance more than three times that normally used in point census studies (e.g. 300 m in Anjos (2007), 200 m in Cavarzere et al. (2013), or 150 m in Wilson et al. (2000)). We used the package *ape* (Paradis, Claude, & Strimmer, 2004) to conduct an a posteriori analysis to test if our sampling locations were spatially correlated or not. We calculated the Moran's I using an inverted matrix of distance between all locations and the number of species registered at each point as a dependent variable. The result indicated that there was no spatial autocorrelation in our locations (observed = −0.0233; expected = −0.0345; p = 0.7759) and, therefore, we assumed that our locations represent independent sampling units.

We used 10 SongMeter SM2 digital recording devices (Wildlife Acoustics, Maynard, MA, USA) to obtain records of birds during three consecutive days in each month from January to May of 2014. We first put the recorders at locations 1–10, and then we moved the recorders to the subsequent locations, completing the 30 sampling locations on the third day. In order to avoid river sounds, which could dominate the recordings, we put the recorders in locations away from any rapids or cascades. The recorders were programmed to start operating at sunrise and to stop two and half hours later. Recordings were made as wav files (48 kHz sampling rate, 16 bits, stereo mode) divided into recordings of 15 min duration with intervals of 5 min between them. Therefore, for each location we obtained eight 15 min recordings per month, which correspond to 60 h/month (30 locations × 2,5 h per point) or 300 h of recording in total.